ROADS And STREETS

Vol. LXVIII Number 3

A GILLETTE PUBLICATION

ESTABLISHED 1906

Fig. 1—Development of a Flood Plain Deposit of Chert Gravel Along the Meramec River, Near St. Louis. (Courtesy Missouri State Highway Department)

THE ORIGIN AND ROAD BUILDING PROPERTIES OF CHERT

By D. G. RUNNER

Assistant Materials Engineer, U. S. Bureau of Public Roads

DURING the past few years, more and more attention has been directed towards the materials used in highway construction. This attention has been focused upon such features as service behavior, ability to withstand the accelerated weathering tests, workability and other items relative to the proposed use. On the other hand, it is believed that little or no attention has been directed toward the origin of these materials, and the reasons why they possess either satisfactory or unsatisfactory road building properties. For example, shale which is being used successfully in road construction in some parts of the United States, is a material that engineers may know how to utilize to the fullest extent, but they possibly have given little thought to its origin. In a previous article[1] a few of the more important features concerning the origin of shale were presented. In this paper another road building material called chert, will be discussed. This discussion will be confined briefly to the origin and general uses of chert in highway construction.

The word chert is believed to have had its origin in the Irish word "ceart," which means pebble. The inference is quite evident since chert is commonly found as nodules or concretions occurring in limestone or dolomite beds or as lenticular masses in other types of rock formations. During long periods of time the calcium from the limestone beds had been dissolved and carried away in solution leaving the chert nodules in an unaltered state. The nodules eventually accumulated by water action into more or less thick deposits in stream beds. This feature, in a measure, probably accounts for the deposits of chert gravel found in the Tennessee River

[1]The Origin and Road Building Properties of Shale, by D. G. Runner, ROADS AND STREETS, Vol. 77, No. 11, 1934.

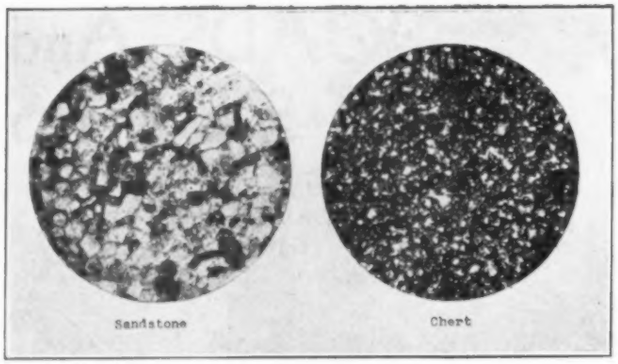


Fig. 2—Thin Sections of Sandstone and Chert Showing the Difference in Texture. (From Bulletin 348, United States Department of Agriculture, E. C. E. Lord)

and in other streams throughout the United States. Figure 1 shows the beginning of a development in a flood plain deposit of chert gravel. It is quite possible that this formation had been formed by the deposition of chert nodules from limestone or dolomite beds miles away from the present location of the gravel.

Chert beds are found ranging in thicknesses of 1 in. to as much as 40 or 50 ft. As the usual thing, however, the formations are not over 20 to 30 ft. in thickness. It is also the usual condition to find the chert beds parallel with the enclosing rock formations. Singularly enough, the line of demarcation is usually sharp and well defined. Chert and flint beds are found in the Cambrian, Ordovician, Silurian and later geologic periods. Geographically they are found chiefly in the south central Mississippi River valley, the Appalachian Mountain area, some parts of the Rocky Mountain region, and in Texas, New Mexico and Arizona.

Definitions of Chert.—Chert is a material the origin of which is much debated. Even the authorities fail to agree upon the manner of its formation. In order to bring out the various conceptions concerning this material, it is thought advisable to give a few definitions of chert. They follow:

"Chert or flint differs somewhat from a normal sandstone in that it is composed chiefly of very finely divided quartz frequently associated with opaline silica that originated from minute siliceous shells of marine animals through a process of chemical solution and deposition." E. C. E. Lord, United States Department of Agriculture Bulletin No. 348, 1916.

"Chert is a rock consisting of chalcedonic and opaline silica, one or both. It possesses homogeneous texture and is usually associated with limestone, either as entire beds, or as isolated included masses." J. F. Kemp, A Handbook of Rocks, 1911.

"Chert will include those crypto-crystalline varieties of quartz which are white, gray, or blue in color. Dark gray to black varieties will be called flint, while those which owe their color to iron oxides will be referred to as jaspers." W. A. Tarr, American Journal of Science, Vol. 44, 1917.

Varieties of Chert.—There are a number of rocks closely associated with, and according to some authorities, practically synonymous with chert. They are flint, chalcedony, hornstone, jasper and novaculite. Flint, which consists of an intimate mixture of quartz and opal, derives its dark color from organic matter. In addition the rock has no cleavage and breaks with a conchoidal fracture. Chalcedony is a compact, crypto-crystalline, dull to resinous rock having a chemical composition of silicon dioxide. The rock has a specific gravity ranging from 2.59 to 2.64, and has a pronounced conchoidal and/or splintery fracture. Hornstone greatly resembles flint, but it is more brittle and has a decided splintery fracture. Jasper is a crypto-crystalline variety of quartz, whose color is chiefly dependent upon iron oxides. It is a chemically precipitated opaline silica, and is often interlaminated with bands and streaks of hematite. Novaculite is composed of silica, extremely fine-grained, conchoidal in fracture and in color is usually white or pale gray. Figure 2 shows the microscopic structure of an ordinary sandstone and a chert. Note the dense matrix of the chert in comparison with the coarse texture of the sandstone.

Theories of the Origin of Chert

The theories concerning the origin of chert are varied and many. It is one subject about which there is a noticeable lack of agreement between geologists and other investigators. Accordingly a number of the more widely accepted and reasonable theories are presented here for the purpose of showing this divergence of opinion. The order of their discussion does not imply that anyone of these is considered to be the correct theory, but is merely the order of arrangement of the topics.

(1) *Replacement of Calcium Carbonate by Silica.*—As is commonly known, chert is usually associated with chalk or limestone deposits. These chert deposits consist essentially of irregularly-shaped nodules or tabular masses which occur as bands or streaks in limestone beds. Sometimes entire beds of limestone have been replaced by chert. Many features appear to substantiate the theory that chert is a replacement of the limestone. According to Tyrrell[2] this condition took place after the origin of the formation. In addition, other features which are indicative of replacement are the formation of chert along cracks or fissures, the irregular nodular shapes, the presence of limestone in chert formations, association of chert with silicified fossils, the preservation of original structures and textures in chert and, in addition, the failure of chert deposits to be confined to definite stratigraphical horizons.

(2) *Deposition of Silica Around Sponge Spicules, Shells, Organic or Organic Remains.*—The fact that chert is quite often found in nodular form lends credence to the belief that silica has been deposited around sponge spicules or other skeletal parts of marine animals. Then too, oolites and other organisms are capable of secreting silica, which no doubt would assume the concretionary or nodular shape, so well known. Van Tuyl[3] states that many of the cherts contain silicified fossils. Many of the compact and dense cherts which appear to possess

[2]The principles of Petrology, G. W. Tyrrell.
[3]The Origin of Chert, F. M. Tuyl, American Journal of Science, Vol. 45, p. 449, 1918.

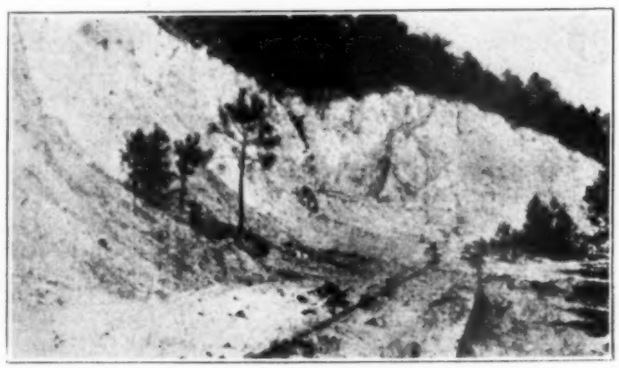


Fig. 3—Chert Pit Located in Chattooga County, Georgia. (Courtesy State Highway Board of Georgia)

Fig. 4—View of an Oiled Chert Gravel Surface Near Scherr, W. Va. (Courtesy West Virginia State Road Commission)

no definite structure will show traces of silicified fossils upon close inspection. These are much more distinct after the chert has been subject to weathering. At times these included fossils still consist of calcite, or are only partially replaced by silica.

(3) *Consolidation of Siliceous Slimes or Oozes Which Were Chemically Precipitated from Sea Water.*—This theory deals with the enormous deposits of radiolarians and diatoms which are found on the ocean bottoms. Some authorities hold that cherts may have been formed by the precipitation of colloidal silica from submarine springs, which were instrumental in producing an ooze in which various organisms became imbedded. These fine sediments may be mixed with calcareous matter, sand, etc., and thus when consolidated shaded into limestones and sandstones.

There are a number of additional theories concerning the origin of chert, but due to limited space will be briefly outlined only.

(4) Precipitation of silica caused by the presence of some mineral such as partially decomposed pyrite.

(5) Growth of nodules in limestone beds, due to the accumulation from silica-bearing ground water.

(6) Chert beds are due to the chemical precipitation, probably at the time of the deposition of the strata in which they occur, or before their consolidation.[4]

Table I shows the chemical analyses of a number of chert samples from the Mississippi valley. Note that the silica content ranges between 98 and 99 per cent, with iron, alumina, magnesia and calcium as minor constituents. In Table II is given the average results of physical tests obtained in the laboratory of the Bureau of Public Roads, on samples of chert from nineteen states. Although only a few hardness and toughness tests are reported, it is believed the values are essentially representative of chert. Figure 3 is a view of a chert pit located in Chatooga County, Georgia.

TABLE I.—REPRESENTATIVE CHEMICAL ANALYSES OF CHERT

	1	2	3	4	5
SiO_2	98.17	98.92	98.71	96.88	98.17
Al_2O_3, Fe_2O_3	.83	.48	.43	2.48	.83
MgO	.01	.02	.02	...	.01
CaO	.05	.03	.03	...	.05
H_2O	.78	.42	.50	...	.78
Total	99.84	99.87	99.69	99.36	99.84

1. Missouri chert.
2. Missouri and Kansas cherts.
3. Missouri and Kansas cherts.
4. Missouri chert.
5. Missouri chert.

TABLE II.—SUMMARY OF TEST RESULTS ON SAMPLES OF CHERT

State	Number Samples	Wt. cu. ft.	Absorption	Per cent wear	Hardness	Toughness
Alabama	7	153	2.65	10.5	...	..
Arizona	3	155	2.35	...	19.3	14
Arkansas	2	159	1.25	10.9	...	..
California	4	170	0.37	13.7	...	..
Florida	7	153	2.66	7.5	...	..
Georgia	4	160	3.72	14.3	...	..
Illinois	7	152	3.01	8.6	...	..
Indiana	1	156	2.83	3.0	...	..
Kansas	1	153	2.45	4.6	...	..
Missouri	6	154	3.17	5.2	19.5	..
Nebraska	1	159	1.33	5.8	...	..
Ohio	2	154	1.96	5.4	...	..
Oklahoma	8	157	2.20	4.5	18.3	15
Pennsylvania	1	125	4.28	6.0	15.0	7
S. Carolina	2	163	0.77	15.6	...	..
Tennessee	4	149	2.32	6.2	18.8	7
Utah	1	162	1.08	29.2	...	..
Virgnia	4	170	0.58	4.3	18.2	14
Wisconsin	2	156	1.87	3.3	19.7	26
Average	..	156	2.15	8.8	18.4	14

Note: Data taken from The Results of Physical Tests of Road-Building Rock, United States Department of Agriculture Miscellaneous Publication No. 76, July, 1930.

Chert in Road Building

Chert has been used for a number of years as road building material, either as a base course for later surface courses, as concrete aggregate, or as a surfacing material. Chert, when crushed, has the advantageous feature of fracturing with angular edges, thus developing an interlocking of the particles when used in bituminous construction. This condition is further emphasized by rolling which tends to increase the stability. Chert in itself as a hard durable rock, composed essentially of silicon dioxide, is weather resistant to a great degree, and on the average shows high resistance to impact. In addition to the true chert, as known by some engineers, there is a gangue material associated with the lead-zinc deposits of Missouri, which is a waste product from the ores. In recent years these "tailings" have been used as surfacing material, which reported satisfactory results.

In Table III is shown the existing mileage of local roads in the United States, including county and township but excluding state highways, at the end of 1930. This table also shows the mileage of sand-clay and top soil, gravel, chert, etc., and water bound macadam in use at this time. It should be noted that there is better than 11 per cent of the total mileage paved with gravel, chert and similar types of surfacing materials.

Standard Specifications for Use of Chert.—In order to show how chert is used in road construction, excerpts

[4]From "A Study of the Cherts of Missouri," E. O. Hovey, American Journal of Science, Vol. 48, p. 401, 1894.

Fig. 5—View of a Chert Road. Federal Aid Project No. 2, Chattooga County, Ga. (Courtesy State Highway Board of Georgia)

Fig. 6—View of Chert Surfacing, Project F-164B, *St. Clair County, Ala. (Courtesy Alabama Highway Department)*

from the standard specifications of Georgia and Alabama are given below. These specifications apply to both chert base and chert surface courses. It should be understood, however, that only the essential features of these specifications are given. The Georgia specification for chert for use in constructing chert base course and chert surface course follows:

Unless otherwise provided in the special provisions, local chert pits or quarries will be furnished by the Highway Department without cost to the contractor but the contractor shall provide and maintain hauling roads to such pits or quarries at his own expense. Imported chert (chert shipped by rail) shall be furnished by the contractor. Any particles of large chert spread on the road shall be broken by hammer or removed before the surface is consolidated. The chert base material shall be composed of hard, durable rock of high resistance to abrasion, with sand and clay or other binding material, and shall be free from thin or elongated pieces. The chert must be crushed and screened unless the special provisions accompanying the proposal form indicates satisfactory chert may be obtained without crushing and screening.

The chert shall meet the following grading requirements:

Total Passing	Percentage by Weight
2 inch screen	100
1½ inch screen	95
¾ inch screen	65–80
¼ inch screen	40–50
10 mesh sieve	30–40

Material below 10 mesh sieve, classed as binder, shall conform to the following percentages by weight:

Clay (finely divided silica)	15-50
Silt	5-25
Total sand	25-80
Sand retained on 60 mesh sieve	15-75

(Note: The above abstracts were taken from "Standard Specifications for Construction of Roads and Bridges," Georgia State Highway Department, 1933.)

The Alabama specifications for chert surface course follows:

CHERT SURFACE COURSE

Description: Chert surface shall consist of a wearing surface composed of chert, constructed on the prepared subgrade in accordance with these specifications and in conformity with the lines, grades, thickness, number of component courses, and typical cross sections shown on the plans.

Materials: Before any chert or binder material is used in the construction of the road surface, it shall first have been approved by the Engineer. In general the Plans or Special Provisions attached to the Proposal Form will indicate the location of pits or quarries from which satisfactory chert may be obtained and

TABLE III.—LOCAL ROADS—EXISTING MILEAGE AT END OF 1930. (ABSTRACTED FROM A REPORT BY THE BUREAU OF PUBLIC ROADS.)

		Surfaced Local Roads by Types		
			Treated and Untreated	
State	Total local mileage	Sand-clay and top soil	Gravel, chert, etc.	W. B. Mac.
Alabama	62,381	8,093	7,523	292
Arizona	20,185	383	1,203	26
Arkansas	60,039	210	1,749	46
California	70,375	...	11,725	2,057
Colorado	59,740	1,381	1,826	...
Connecticut	12,022	...	985	396
Delaware	2,962	...	161	226
Florida	23,703	3,954	962	5,312
Georgia	95,160	9,143	1,291	75
Idaho	35,260	2,054	4,895	...
Illinois	87,398	...	12,798	429
Indiana	67,657	...	42,966	1,126
Iowa	95,643	...	13,544	...
Kansas	123,550	500	2,100	69
Kentucky	46,261	165	3,101	6,132
Louisiana	25,044	60	4,570	11
Maine	18,843	8	4,295	13
Maryland	11,594	...	1,610	1,115
Massachusetts	17,178	17	5,355	736
Michigan	72,997	84	15,256	1,398
Minnesota	103,770	5,927	24,234	101
Mississippi	55,856	204	12,155	18
Missouri	102,094	1,200	5,543	1,450
Montana	58,924	120	1,900	2
Nebraska	84,155	500	1,045	3
Nevada	19,802	38	652	...
N. Hampshire	9,486	24	562	24
New Jersey	15,520	162	3,834	1,155
New Mexico	38,442	78	265	...
New York	68,360	...	10,599	4,147
N. Carolina	45,091	12,595	850	175
N. Dakota	99,445	...	843	...
Ohio	73,763	...	30,687	5,115
Oklahoma	114,484	169	1,674	2
Oregon	47,265	350	8,270	1,200
Pennsylvania	77,366	...	12,491	2,487
Rhode Island	1,730	...	278	124
S. Carolina	51,733	13,197	572	7
S. Dakota	114,295	...	3,112	...
Tennessee	60,909	236	8,296	2,924
Texas	169,836	2,584	12,300	467
Utah	20,219	15	2,432	...
Vermont	10,827	144	1,375	...
Virginia	52,269	3,849	1,712	1,320
Washington	40,633	975	10,275	1,704
W. Virginia	30,635	...	655	690
Wisconsin	71,563	3,391	15,542	951
Wyoming	38,106	97	240	...
Total	2,684,570	71,907	310,308	43,527

Fig. 7—View of Chert Surfacing in Alabama. (Courtesy Alabama Highway Department)

also indicate whether crushing and screening of the chert will be required. Unless otherwise provided in the Special Provisions, local chert pits or quarries will be furnished by the Department without cost to the Contractor, but the Contractor shall provide and maintain roads necessary for hauling from such pits or quarries at his own expense. Imported chert shall be furnished by the Contractor. Any particles of large chert spread on the road that fail to pass the screen requirements shall be broken by hammer or removed before the surface is compacted. The chert surfacing material shall be composed of hard, durable rock of high resistance to abrasion, with sand and clay or other satisfactory binding material, and shall be free from thin or elongated pieces. The chert shall meet the following grading requirements:

Total Passing	Percentage by Weight
2 inch sieve	100
1½ inch sieve not less than	95
¾ inch sieve	25 to 80
No. 4 sieve not more than	50
No. 10 sieve not more than	40

Material below 10 mesh sieve, classed as binder, shall conform to the following:

	Per Cent
Clay (finely divided silica)	20 to 50
Silt	10 to 25
Total sand	25 to 60
Sand retained on 60 mesh sieve	15 to 65

Construction Methods: The chert surface course shall be constructed in accordance with the following method: (a) Spreading the material. Prior to the placing of any surfacing material, the subgrade shall be prepared in accordance with the requirements of Section 24. No material shall be placed upon the subgrade until the subgrade has been subjected to traffic for at least thirty days, unless otherwise directed by the Engineer. All holes, ruts, defects, or soft places occurring in the subgrade, by reason of traffic, hauling or other cause, shall be corrected before surfacing materials are placed. Completed and compacted subgrade equal to the length of surface that the Contractor proposes to lay the next working day shall be maintained at all times ahead of placing surfacing material. Side boards shall be used to secure the proper depth and alignment, and shall be kept securely in place at least 200 feet in advance of the dumping and shall not be removed until the surfacing material is properly spread and the shoulders brought to the required cross section. The surfacing material shall be spread by hand from dumping boards on the prepared subgrade, or by means of approved vehicles and spreading devices; but in each case it shall be distributed uniformly during the process of dumping to such a depth that when compacted the surface will have the thickness shown on the Plans.

If after spreading the surfacing material, it is found not to be uniform in composition, it shall be thoroughly mixed by plowing and harrowing until the entire mass is of a homogeneous composition.

The Contractor shall use a template placed on the side forms to check the cross section and depth of the loose material. Care shall be used in spreading and mixing the surface material so that no irregularities in contour will develop during compaction.

(b) Mixing surface material. When it is necessary to mix binder material with chert, the method of mixing the two materials shall be as specified in Section No. 46.

(c) Compaction. When the material used has been properly spread and mixed, as specified above, the side boards shall be removed and the space occupied by them filled with shoulder material and thoroughly compacted by tamping. It shall then be compacted by rolling as specified in Section No. 46, if rolling is specified in the Special Provisions.

If the traffic on the road is deemed of sufficient volume to insure compaction, the Contractor shall, if rolling is not required in the Special Provisions, accomplish the compaction by permitting traffic over the road, and the surface shall be constantly machined and dragged and kept free from ruts, depressions and bumps until the surfacing material has compacted smooth and conforms to the cross section shown on the Plans. This applies to both courses of two course construction.

(Note: The above abstracts were taken from "Standard Specifications for Earthwork, Base Courses, Surface Courses, Pavements, Structures, Design of Structures," Alabama State Highway Commission, 1933.)

Thorough traffic studies have shown that chert, topsoil, shale and similar materials are capable of satisfactorily carrying 100 to 300 vehicles per day. In fact, C. N. Conner in his report on "Low Cost Improved Roads" of 1928, states that chert surfaces in Georgia and Alabama give a daily service of 800 vehicles. Based upon this data, it is evident that chert possesses some properties that are suitable for base or surface course construction. There are a great many localities in the United States where deposits of chert are found, and it is believed that this material could be used economically on the secondary, or even the primary, road systems. Figures 4 to 7 are included to illustrate the types of surfacing constructed with chert in the States of West Virginia, Georgia, and Alabama.

BIBLIOGRAPHY

(On the origin of chert)

1. The Orgin of Chert and Flint, W. A. Tarr, University of Missouri Studies, vol. 1, No. 2, 1926.
2. The Use of the Terms Flint and Chert, W. S. Glock, Iowa Academy of Sciences, Proceedings, vol. 27, p. 167, 1922.
3. Origin of Chert in the Burlington Limestone, W. A. Tarr, American Journal of Science, vol. 44, 4th Series, p. 409, 1917.
4. The Formation of Missouri Cherts, R. S. Dean, American Journal of Science, vol. 45, p. 411, 1918.
5. The Origin of Chert, F. M. Van Tuyl, American Journal of Science, vol. 45, 4th Series, p. 449, 1918.
6. A study of the Cherts of Missouri, E. O. Hovey, American Journal of Science, vol. 48, p. 401, 1894.
7. Notes on the Mississippian Chert of the St. Louis Area, D. C. Barton, Journal of Geology, vol. 26, p. 361, 1918.

(On the properties of Chert)

8. A Preliminary Report on the Roads and Road-Building Materials of Georgia, S. W. McCallie, Geological Survey of Georgia, Bulletin 8, 1901.
9. Chert Unfit for Coarse Aggregate in Concrete, F. V. Reagel, Engineering News-Record, vol. 93, No. 9, August 28, 1924.
10. The Stability of Chert, H. F. Kriege, Rock Products, vol. 32, No. 9, p. 50, April 27, 1929.

▼

Cost of Drilling Concrete with Portable Rotary Shot Drills

The Bureau of Maintenance of the Missouri State Highway Department has been using portable rotary shot drills for drilling 2½ in. diameter holes in concrete pavements in connection with the mud jack system of raising the slabs. The drill, powered by a gasoline engine is mounted on a small four-wheel chassis. A slow motion power drive facilitates movement of the drill from hole to hole. The machine is equipped with brakes and steering lever. For long moves, the machines are loaded on specially equipped motor trucks. Two drills and one motor truck make a working unit.

Highway Research Abstracts for February gives the following costs of this work, the matter being taken from an unpublished report by C. P. Owens, Missouri Engineer of Maintenance:

COST OF DRILLING HOLES IN CONCRETE PAVEMENTS WITH PORTABLE ROTARY SHOT DRILLS. (2½ IN. DIAMETER HOLES)

Type of Aggregate	Hours worked	Holes drilled	Cost—Total	Cost—Per hole, cts.	Minutes per drill per hole
Gravel, plain	1630.5	11,315	$ 7,296	64.8	17.1
Gravel, reinforced	540.5	2,261	2,535	112.0	28.5
Limestone—plain	2513.5	40,982	10,582	25.8	7.3
Limestone—reinforced	398.0	4,123	1,727	41.9	11.5
Total	5082.5	58,681	$22,142		
Average				37.7	10.3

▼

CITY AND COUNTY GOVERNMENTS TO BE CONSOLIDATED.—Consolidation of city and county governments have been approved at Milwaukee, Wis., and Jacksonville, Fla.

PRACTICAL SOIL STABILIZATION

By C. A. HOGENTOGLER

Senior Highway Engineer,
U. S. Bureau of Public Roads

EARTH structures lose stability mainly as a result of soil being squeezed out from beneath the loaded area. Such displacement or lateral flow of the soil is responsible for the failure of fills due to sliding, the penetration of subgrade soil into the interstices of porous base courses, and the rutting of subgrades and base courses. See Fig. 1.

The Theory of Stability Discussed.—Soil movement during loss of stability or rutting is illustrated by Fig. 2. It is assumed that the load is applied for an indefinite length over a width of 2b. For deformation under the load to occur, the Section *A* must shear along some plane such as *S* and displace laterally as indicated in Fig. 2, *B*. But the same time the adjacent section marked *C* must shear along some surface as *S'* and, in consequence, displace upward forming a bulge adjacent to the loaded area as shown in Fig. 2, *C*.

Actually, the surfaces *S* and *S'* may be parts of a continuously curved surface but, for mathematical treatment, they may be considered as separate plane surfaces without introducing a large error.

If rutting is to be prevented, the prism *C* must resist displacement sufficiently to prevent the lateral bulging of the prism *A*. This may be accomplished by two

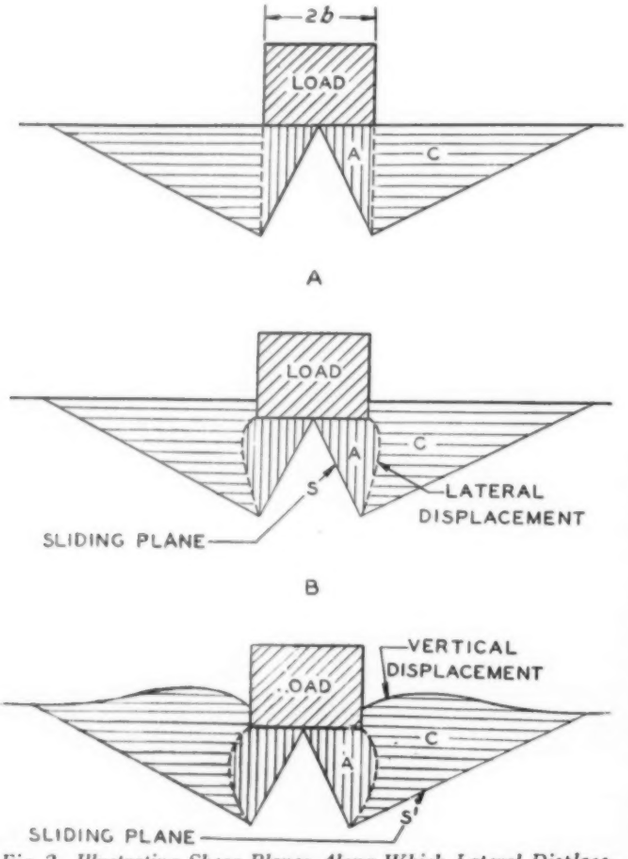


Fig. 2. Illustrating Shear Planes Along Which Lateral Displacement of Soils Occurs

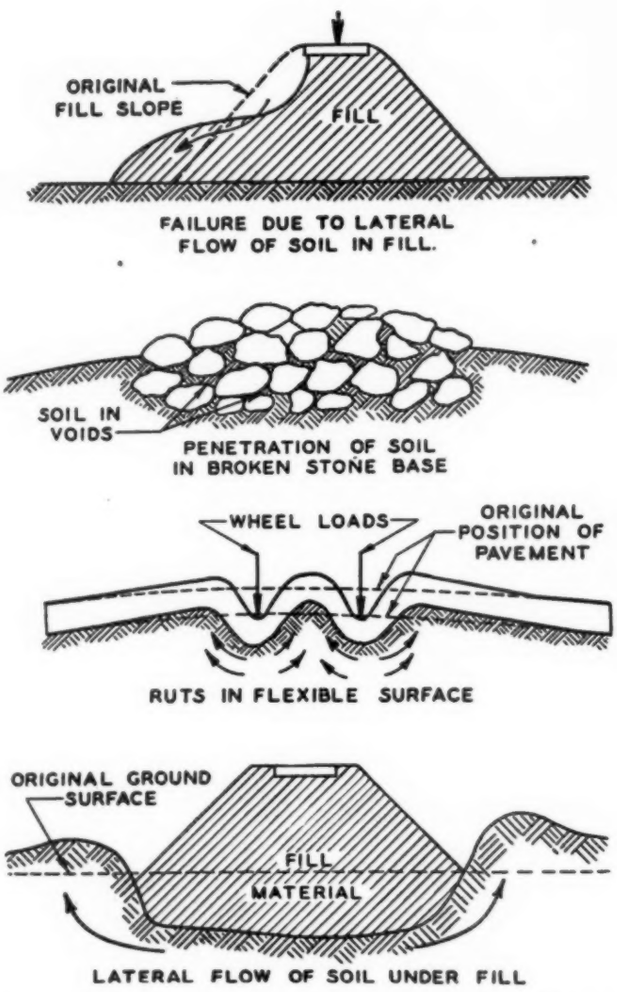


Fig. 1. Illustrating Type of Failures Due to Loss of Stability in Soils.

means, separately or in some combination. The shear strength along the plane *S* and *S'* must be sufficiently high to prevent sliding of the prisms or sufficient pavement weight must be placed adjacent to the loaded area to prevent the upward bulging of the prism *C*.

Combined Internal Friction and Cohesion Control Shear Strength.—Table I gives theoretical values of supporting values for conditions of load as shown in Fig. 2, and serves to illustrate the effect of internal friction and cohesion. These data disclose that the supporting value of clay soils may drop from as much as about 12,000 lb. per square foot to less than 400 lb. per square foot due to drop in cohesion.

While the stability of a cohesionless sand may be less than 300 lb. per square foot and that of a fairly stiff clay about 5,000 lb. per square foot, these two materials properly combined might have a supporting value of more than 17,000 lb. per square foot. As a matter of

Fig. 3. Sand-Clay Road, Muscogee County, Georgia.

fact, only the cohesion of an almost liquid clay, about 130 lb. per square foot, is required to increase the supporting value of cohesionless sand from 270 lb. per square foot to 2,500 lb. per square foot.

The internal friction is furnished by such materials as sand, gravel, slag and crushed stone, which usually comprise the granular aggregate.

Cohesion is furnished by crystalline chemical formations in portland cement mixtures; bitumen, in tar and asphaltic mixtures; rock or slag powder and moisture films in crushed stone, slag and gravel mixtures; colloidal clays and moisture films in top soil, sand-clay, and similar light-textured soils; and moisture films alone in beaches stabilized temporarily by the tides.

Whether the mixture of granular material and binder becomes a stabilized subgrade, a soil road surface, or a high type pavement depends more on the grading and the methods of construction than upon either the kind of materials or basic theory.

Binder applied to aggregate already placed produces cement-bound macadam when the binder is portland cement; bituminous macadam, when the binder is tar or asphalt; waterbound macadam, when the binder is rock or slag powder; and granular material stabilized with clay when the binder is soil.

Aggregate applied to binder already placed results in the old German sandwich type of concrete pavement; bituminous surface treatment; upside down macadam type or clay stabilized with granular material, depending upon the kind of binder used.

Aggregate and binder mixed before placement on the roadbed becomes cement concretes, bituminous concretes, traffic-bound slag and crushed stone surfaces or sand-clay and sand-clay gravels, depending on the kind of binder used.

Regardless of the type of construction, the ultimate stability of the mixture depends upon the permanent adhesive strength which can be developed by the minute binder films which connect the soil particles. This strength depends not only on the characteristics of the moisture, bitumen, or crystalline binders, but also upon those of the soil particles and the films of gas or other substances with which the soil particles may be covered.

The assumption that soil consists of inert solids of constant volume, and of pores which enlarge and shrink as the soil mass changes in volume is valid enough for use in the interpretation of the results of the physical soil tests. However, as a result of the disintegration, degradation and decomposition of rocks, and of the influences of animal and plant life, soluble materials, gels

TABLE 1—INFLUENCE OF INTERNAL FRICTION AND COHESION UPON THE STABILITY OF SOILS.

Soil types	Cohesion, c Lb. per sq. ft.	Angle of internal friction, ϕ Degrees	Supporting value, q[1] Lb. per sq. ft.	Cohesion c required to increase q to 2,500 lb. per sq. ft. Lb. per sq. ft.
Clay, liquid	100	0	400	...
Clay, very soft.....	200	2	860	...
Clay, soft	400	4	1,850	...
Clay, fairly stiff.....	1,000	6	4,970	...
Clay, very stiff.....	2,000	12	12,490	...
Sands, dry	0	34	270	131
Cemented sand and gravel	1,000	34	17,340	...

[1]Computations on assumptions that weight of the soil equals 100 pounds per cubic foot and width of loaded area equals 3 inches.

and bacteria also are usually present.[1] The important bearing which such materials may have upon the selection of admixtures for use in the stabilization of soils is suggested by the theory of adsorption as presented by Bancroft[2] and summarized in the section to follow.

Matter in Film Phase.—All solids tend to adsorb or condense on their surfaces any gases or vapors with which they are in contact. For a liquid to wet a solid in the presence of air, the liquid must be adsorbed more strongly than the air and must displace the air. Due to adsorbed air on the surface of the solid, drops of rain, after a period of drought, will often roll along dust without wetting it.

A drop of water, as from an oar of a boat or paddle of a canoe, may fall on a sheet of water, become submerged and then emerge with the upper portion of the drop apparently unwetted by the liquid with which it has been covered.

All campers are familiar with the unpleasant fact that touching canvas with one finger will cause a tent to leak in the rain. It matters not whether the touching is from the inside or the outside. It either contracts the air spaces and drives out the air so that the water enters when the finger is removed, or it expands the air spaces and allows water to run in. Either way, air is displaced at that point and water enters.

Change in the electrolytic properties also may facilitate the wetting of materials. It has been found that

[1]The Soil Solution, by Frank K. Cameron, The Chemical Publishing Company, Easton, Pa., 1911, and Williams and Norgate, 14 Henrietta Street, Covent Gardens, London, England.
[2]Applied Colloid Chemistry, by W. D. Bancroft, McGraw-Hill Book Company, Inc., 1932.

Fig. 4. Loose Surface Type Stone Road, State Road No. 46, Indiana.

Fig. 5. Same as 4 After Treatment with Calcium Chloride

mercury wets platinum only when a current is flowing. At other times there is evidently an air film.

A vertical jet of water breaks into drops which scatter because an enclosing film of adsorbed air causes the drops to rebound when they strike one another. A feebly electrified body brought close to the jet causes the air films to be removed to such an extent that the drops coalesce and form a coherent stream. It is possible to press together two soap bubbles, which are merely hollow drops, with considerable force without causing them to coalesce unless they are electrified slightly, when they coalesce readily without bursting. Dr. F. E. Hance has observed that samples of soil which resist slaking indefinitely when immersed in distilled water may disintegrate almost instantaneously when immersed in drinking water from the faucet containing electrolytes in solution.

The selective character of the adsorption of adhesives in soil stabilization is indicated by the reports of Winterhorn,[3] and Reagel and Schappler[4] of the Missouri State Highway Department.

Their work discloses that some bases have greater affinity for bitumen than for water and that the reverse is true for other bases. Pretreatment with soap facilitates the mixing of some soils with bituminous materials. The greater adhesion of the oil for the soil afforded by the soap pretreatment was demonstrated when a heavy rain washed the soil from a commonly constructed earth-gravel oil mixture but did not wash it from the soap treated section. It was indicated also that different soaps may be desirable for different soils. For every soil it is possible to select a location for exchange which will adjust the properties of the soil as desired.

Adsorbed Films Have High Densities.—Some conception of the enormous density of adhesive films is furnished by the thought that the transition of a pure liquid to its own vapor is not abrupt but that over a narrow range all the densities intermediate between those of vapor and of the liquid actually occur. Williams[5] has suggested that the first layer of an adsorbed gas vapor may be under a pressure of as much as 10,000 atmospheres, graded then from the corresponding density to that of the liquid in bulk in the outermost layer. The transition film for carbon dioxide is said to be about 3 ten millionths of an inch thick.

[3]Oiling Earth Roads. Application of Surface Chemistry, by Hans Winterkorn, Industrial and Engineering Chemistry, vol. 26, August, 1934.

[4]Stabilizing Sand and Gravel Surfaces, by R. C. Schappler, Kansas Highway Conference, Manhattan, Kansas, Feb. 5, 1934.

[5]Proceedings of the Royal Society, vol. 98A, 1920, p. 223.

Water also changes in character with diminishing size of film. Drops 1/40,000 of an inch to about 1 millionth inch in size, suspended in the air, appear as fog if you walk through them and as a cloud if you look at them from a distance. Under electrical stress they coalesce to form raindrops at sizes of about 2/1,300 in. to ¼ in. in size, which eventually become moisture films in soils.

Moisture filling the pores of sandy and silty soils and of clay soils above the plastic limit has, in general, the evaporation and freezing characteristics and the surface tension of water in bulk. When drying or mechanical compaction reduces the density of the clay below that at the plastic limit, the boiling point of the film rises, the freezing point lowers, the surface tension increases so that these films become somewhat tougher than water in bulk.[6] This causes the soil to change from a plastic to a semisolid material. In thicknesses below 2 millionths of an inch, the films behave, according to Terzaghi, like semisolid substances.[7]

Wetting Power Disclosed by Simple Apparatus.—Wettability of the solid should be distinguished from wetting power of the liquid. Wettability represents the tendency of a solid to be wetted and may be expressed in terms of energy per area of surface. Wetting power represents the attractive force which the liquid exerts on the solid and may be expressed in terms of attractive force. Various means for determining this force have been suggested.

As early as 1896 different forms of apparatus were described (see Bancroft) in which water evaporates through a porous tube or a porous cup of plaster into dry air. As the water evaporates off, mercury is drawn up into the tube and if bubbles of air do not form, can reach incredible heights, limited by the tensile strength of the liquid.

The drainage indicator described before the Highway Research Board[8] in 1931 utilized this principle, as does also one modified form.

The greater the adhesion attraction the higher above the water table will moisture wet the surfaces of soil particles. The high tensile strength of water causes columns of moisture to be drawn up into the soil as the surface coating films, acting like thin elastic rubber diaphragms, proceed along the walls of the soils' pores.

For equal pore size, the greater the adhesive attrac-

[6]Simplified Soil Tests for Subgrades and Their Physical Significance, by Charles Terzaghi, Public Roads, vol. 7, no. 8, October, 1926, p. 154.

[7]Physical Review, vol. 16, 1920, p. 56.

[8]Present Trend of Subgrade Research, by C. A. Hogentogler and E. A. Willis, Proc. 12th Annual Meeting of the Highway Research Board, December, 1932.

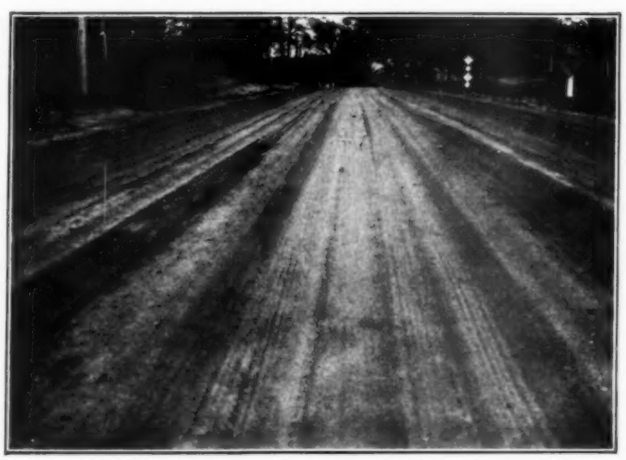


Fig. 6. Salt Treated Gravel Road, Michigan.

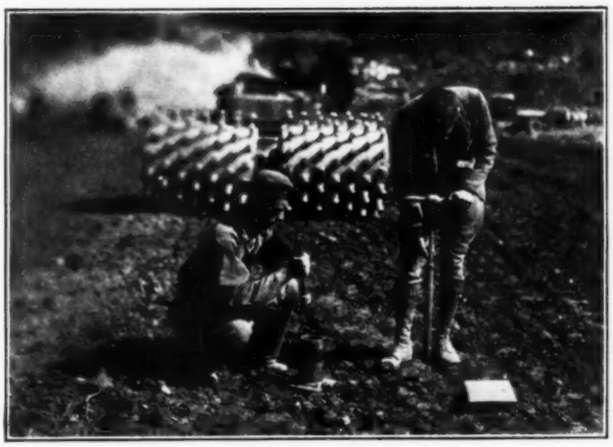


Fig. 7. Proctor Compacting Cylinder (Left) and Plasticity Needle (Right).

tion the higher will be the capillary rise. For equal adhesive attraction, the height to which capillary moisture will rise increases as the diameters of the pores decrease. The force which lifts the moisture columns depends upon the circumference of the capillaries. The weight of columns depends upon the cross-section areas of the pores. As the pores become smaller the ratio of circumference to area increases. The lifting power thus increasing at a faster rate than the weight to be lifted accounts for the increasing height of capillary rise with decreasing pore size.

In sands the ratio of circumference of pore to area is so small that detrimental capillary rise is not to be expected. In silts (particles between .05 mm. and .005 mm.) the circumference-area ratio is sufficiently small to produce capillary rise of several feet or more. The pore area is large enough to facilitate the movement of moisture and this combined with the fact that the films retain the properties of water in bulk phase causes capillary moisture in silts to rise rapidly enough to produce frost heave. However, such films do not furnish the cohesion required in soil binders.

In clays (particles smaller than .005 mm.) capillary moisture may rise to much greater heights than in silts. The pores, however, may become small enough to retard the flow of moisture, which combined with the fact that the films may be more viscous than water in bulk, usually prevents the capillary moisture in plastic clays from rising fast enough to produce frost heave. It is this type of film which furnishes the cohesion required in soil binders.

Capillary moisture entering unconfined soils may separate the particles to such an extent as to cause the soil mass to lose all semblance of stability. In confined soils the entrance of capillary moisture may be productive of enormously high pressures.

When the pores are filled with moisture the attractive force of moisture for soil particle has been satisfied. Consequently, there is no tendency for additional moisture to enter the pores due to capillarity even in soils compacted to high density. Under these conditions expansion may occur due to elastic rebound of the soil particles but not to capillarity.

The relative resistance of wet and dry soil samples to the entrance of capillary moisture is demonstrated by experiments reported in Public Roads of June 1931.

Two disks cut from each of a number of compressed soil samples were immersed in water—one in the wet state and the other after being dried to constant weight. Sixty-seven of the disks immersed in the wet state remained intact after being immersed for an average period of 9 months. The corresponding disks, immersed in the dry state, disintegrated after being immersed for periods ranging from 10 minutes to one hour.

Adhesive Films Capable of Furnishing Enormous Cohesion.—The very fine vapor films have an adhesive power so great they cannot be removed from glass by heating at a temperature up to 500° C. nor from soils by forces of from 9,000 to 15,000 atmospheres. Keen[9] showed that samples of sand grains with binder of clay colloids can be 19 times as strong in compression as similar samples of sand grains with an equal proportion of portland cement binder.

In the frosted glass industry, gelatine or glue coatings drying on rather thick glass exert a tenacity high enough to tear away the surface of the glass itself, chipping it into fern-like patterns. A brittle glue will give a different pattern from a tough glue and the addition of salts also modifies the patterns.

The theory of adhesion depends in part on the fact that the cementing material adheres strongly to the two surfaces and hardens there. For a given adhesive and given materials the thinnest film gives the strongest joint. The thickness of films depends upon both the adhesive and the materials to be cemented. A slight change in the electrolytic properties of the latter is sufficient to cause a considerable variation in the thickness of the adhesive film and consequently in the strength of the resulting joint.

Thus, means to provide a strong and lasting joint between soil particles and the adhesive films connecting them becomes the basic consideration in the stabilization of soils.

Methods proposed for accomplishing this purpose include the use of admixtures, mechanical consolidation and waterproof coverings.

The admixtures are:

1. Soil materials of the proportions and the character to furnish the grading which causes the contained moisture films to have high adhesive strength.
2. Deliquescent chemicals to provide the moisture films in soil mixtures with strength more uniform and lasting, under conditions of changing atmospheric moisture and precipitation, than that due to the grading of the soil materials alone.
3. Chemicals with the electrolytic properties required to facilitate the replacement of existing films of air or natural gels on soil particles with moisture or other adhesives in thin films of high strength.
4. Adhesives to furnish films more substantial than those of moisture alone to permanently destroy the

[9]The Physical Properties of the Soil, by Bernard A. Keen. Longmans Green and Company, 1931.

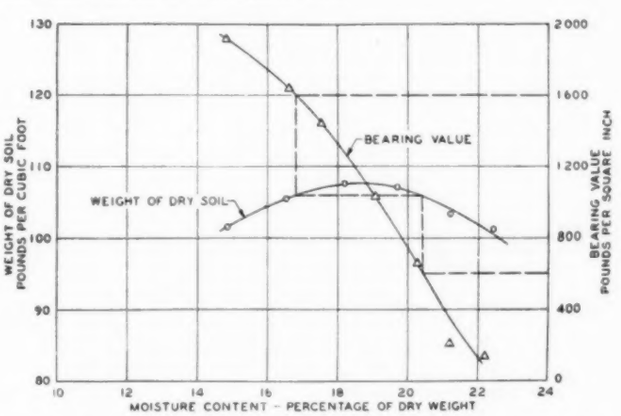


Fig. 8. Dry Weight-Moisture Content and Consistency-Moisture Content Curves Furnished by Proctor Tests.

clay and colloidal properties responsible for detrimental volume change in soil mixtures.

The consolidation required to furnish well graded materials with a high but more or less qualitative degree of density may be obtained partly by rolling during construction and in part by the action of traffic afterward. In the stabilization of poorly graded or fine grained materials, whether for use as base courses, subgrades or embankments, consolidation to provide a quantitative degree of density predetermined by test, is required as part of the construction procedure. The terms, compaction for the qualitative type and densification for the quantitative type are used to distinguish the two kinds of consolidation.

Waterproof coverings are to protect the densified mixtures from evaporation of moisture films and subsequent softening with change from dry to wet weather.

Essential Features of Well Graded Materials.—Graded materials required to make firm and hard road surfaces consist of coarse aggregate and soil mortar. The coarse aggregate is that portion retained on the No. 10 sieve and includes particles of natural gravel, supplemented when necessary with crushed stone or slag. See Fig. 3.

The mortar includes coarse sand or other granular material passing the No. 10 sieve and retained on the No. 60 sieve; fine sand passing the No. 60 sieve and retained on the No. 270 sieve; silt, clay and moisture.

The coarse aggregate and coarse sand furnish structural strength and hardness; fine sand adds an embedment support to the coarse sand; silt acts as a filler to prevent the granular particles from rocking; and clay and colloidal particles provide pores minute enough to cause connecting moisture films which produce high cohesion.

Satisfactory mixtures are designed to have interlocking of grains and capillary moisture forces sufficient to furnish the granular aggregate with high stability during wet weather and enough cohesion in the binder soil to maintain the integrity of the surface during dry weather.

The degree to which mixtures satisfy these requirements is indicated by the grading of the entire soil sample and the plasticity limits of the fraction of soil passing the No. 40 sieve.

The grading of mixtures which should prove satisfactory is designated by the following composition limits, by weight:

[19]Material of greater maximum size can be used under certain conditions, but the largest aggregate should never exceed one-third the thickness of the stabilized layer nor more than 10 percent greater than 1 inch. The fraction passing the No. 270 sieve should be less than two-thirds the fraction passing the No. 40 sieve.

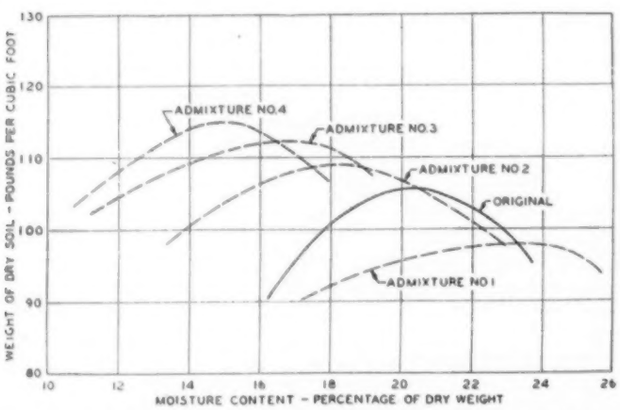


Fig. 9. Curves Showing Effect of Admixtures on Dry Weight-Moisture Content Relationships.

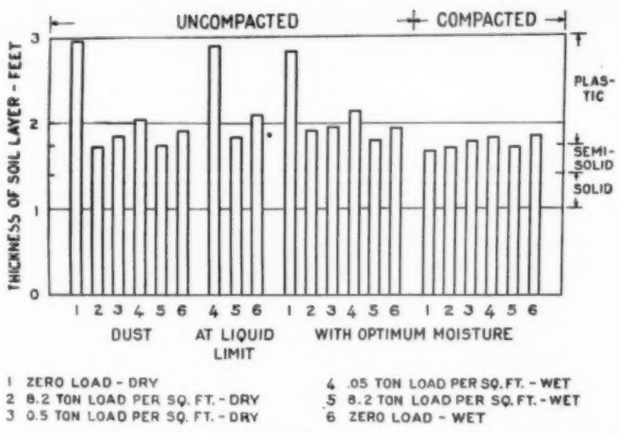

UNCOMPACTED
COMPACTED
THICKNESS OF SOIL LAYER - FEET
3
2
1
0
PLAS-TIC
SEMI-SOLID
SOLID
1 2 3 4 5 6 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6
DUST
AT LIQUID LIMIT
WITH OPTIMUM MOISTURE
1 ZERO LOAD - DRY
2 8.2 TON LOAD PER SQ. FT. - DRY
3 0.5 TON LOAD PER SQ. FT. - DRY
4 .05 TON LOAD PER SQ. FT. - WET
5 8.2 TON LOAD PER SQ. FT. - WET
6 ZERO LOAD - WET

Fig. 10. Showing But Small Change in Volume of Densified Sample as Compared with That of Other Samples of the Same Soil.

Passing	Per Cent
1-inch screen	[19]100
¾-inch screen	85-100
⅜-inch screen	65-100
No. 4 sieve	55- 85
No. 10 sieve	40- 65
No. 40 sieve	25- 50
No. 270 sieve	10- 25

Liquid limits up to about 20 or slightly more indicate sandy materials with negligible capillarity. Liquid limits up to about 35 indicate the capillarities which may be expected in satisfactory binders.

The greater the plasticity index for equal liquid limits the more is indicated that the capillarity is due to the presence of the clays which furnish cohesion, and consequently, the greater is indicated the cohesion of the material. Generally, plasticity indexes of about 3 or less indicate sufficient binder cohesion for use in road construction under unusually wet conditions; 4 to about 8, under conditions of average moisture; and 9 to 15 inclusve, only under dry or arid conditions. Plasticity indexes exceeding 15 indicate soils not suitable for road surfacing.

As additional guide in the selection of binders for use in road construction under unusually wet conditions, field moisture equivalents up to 21, 21 to 25 inclusive, and exceeding 25 indicates, respectively, high, medium and low resistance to softening.

Deliquescent Substances Used to Prevent Excessive Loss of Moisture in Dry Weather.—Absence of moisture films from soil road surfaces causes dust and raveling; too much moisture causes rutting. The dryer a road surface becomes as a result of evaporation, the wetter a rain will make it. This is because extreme dryness causes small cracks and fissures to form in the clay binder through which rain water may enter and soften the interior of the road surface. Fissures do not form in damp surfaces of properly selected constituents and water will be shed from the surface without injurious effect.

Dampness of surface is desirable for another reason. All types of top-soil, gravel, traffic-bound and even waterbound macadam road surfaces acquire their final consolidation through compaction by traffic during what might be termed a period of seasoning following construction. When the surfaces are dry during this period the mineral binder powders under traffic and permits ra-eling of the surface productive of surface roughness which requires extensive patching of the macadam and maintenance by means of mulch on the other types.

If such surfaces can be maintained in a damp or slightly moist state the moisture films in the minute

Fig. 11. Road Surface Consisting of a Base Course of Soil Stabilized with Portland Cement and a Thin Bituminous Surface Treatment. South Carolina.

pores of the binder will prevent the separation of the granular particles and the shocks and blows produced by traffic become effective in gradually wedging the granular fragments into close association. The cohesion increases as the pores in the binder become smaller and finally the coarse aggregate, the sand, the filler and the binder are formed into a stable, durable road structure.

Calcium chloride[11] is the principal chemical used in this type of stabilization although common salt has been used to a limited extent in experimental sections. The hygroscopic property of calcium chloride causes absorption of moisture from the air during periods of high humidity and also slows up the rate at which soils lose moisture.

The high density attained during compaction by traffic is indicated by dry weights of as much as 150 lb. per cubic foot which have been observed for wearing courses treated with calcium chloride and common salt.

Permanent Densification of Soils a Promising But Little Explored Method.—The procedure is to treat the soil with just enough moisture or other adhesive to satisfy its adsorptive attraction at a desired state of density and to provide this state of density by suitable methods of compaction.

In 1925, Milburn[12] showed that there is an optimum binder content at which maximum density of bituminous mixtures may be attained and in 1928 Jackson[13] stated that it was generally known that there is an optimum water-cement ratio for each portland cement concrete mixture.

Proctor,[14] in a series of reports, has shown that for every soil there is a moisture content at which maximum compaction can be obtained with a sheepsfoot roller during construction. The extent of this compaction is readily ascertained by testing samples at different moisture contents under impacts of a standard tamper in the laboratory.

Compaction Tests Discussed.—In the Proctor tests, soil samples are compacted at different moisture contents in a 1/30-cu. ft. cylinder by the impact of a 5½-lb. rammer and the density of the compacted soil is computed from the actual weight of soil and the moisture content and expressed in pounds per cubic foot. The bearing power of the compacted soil is determined for each moisture content by measuring the force needed to push a needle of known end area into the soil at a speed of ½ in. per second.

Figure 7[15] shows the compacted fill material being tested with the plasticity needle. In the background is the type of sheepsfoot roller used to compact the fill.

Figure 8 shows the two curves resulting from the test; the weight of dry soil-moisture content relation and the bearing value-moisture content relation. The weight of dry soil-mixture content curve discloses that a moisture content of about 19 per cent, with a corresponding bearing value of about 1,100 lb. per square inch, is required if maximum compaction is to be attained.

If, at the specified compaction, the bearing value of this particular soil is indicated by the plasticity needle to be higher than 1,100 lb., the increase can be considered as only temporary if the fill is to be unprotected from water after construction. Thus a bearing value of 1,600 lb. per square inch indicates a moisture content of slightly less than 17 per cent. This corresponds to a dry weight of about 106 lb. per cubic foot. At this density the soil can take up moisture to a maximum of slightly more than 20 per cent which, in turn, corresponds to a bearing value of but 600 lb. per square inch.

Figure 9 illustrates how dry weight moisture content curves may be used to disclose the effect of various admixtures in increasing or decreasing the stability of soil. Curves furnished by tests of samples treated with admixtures which serve to decrease the density are lower and to the right of the curve furnished by tests on the untreated sample. See admixture No. 1.

Curves furnished by tests of samples treated with admixtures which serve to increase the density are higher and to the left of the untreated soil curve. See Nos. 2, 3 and 4.

Decrease in the degree of compaction has the same effect as admixtures which serve to reduce the density. Increase in the degree of compaction serves to increase the obtainable density.

The extent to which samples of densified soil will deform under change of load or expand in the presence

[11] See Proc. Twelfth Annual Meeting Highway Research Board, Part II. Report by Fred Burggraf.
"Stabilized Soil-Bound Road Surfaces," by W. R. Collings and L. C. Stewart, Engineering News-Record, May 24, June 7 and June 14, 1934.
"Soil Stabilization and Low Cost Roads," by B. C. Tiney, Canadian Engineer, October 17, 1933.
"Stabilizing Michigan Gravel Roads with Clay and Calcium Chloride," by E. E. Blomgren and J. W. Kushing, Public Works, January, 1934.

[12] "A Deformation Test for Asphaltic Mixtures" by H. M. Milburn, Public Roads, Vol. 6, No. 6, August, 1925.

[13] "The Design of Pavement Concrete by the Water-Cement Ratio Method," by F. H. Jackson, Public Roads, vol. 9, no. 6, August, 1928.

[14] "Fundamental Principles of Soil Compaction," by R. R. Proctor, Engineering News-Record, vol. 111, No. 9, August 31, 1933;
"Field and Laboratory Determination of Soil Fertility," by R. R. Proctor, Engineering News-Record, vol. 111, No. 10, September 7, 1933;
"Field and Laboratory Verification of Soil Suitability," by R. R. Proctor, Engineering News-Record, vol. 111, No. 12, September 21, 1933;
"New Principles Applied to Actual Dam Building," by R. R. Proctor, Engineering News-Record, vol. 111, No. 13, September 28, 1933.

[15] Figures 7, 8 and 9 supplied by C. A. Hogentogler, Jr., Soils Engineer, Back Creek Earth Dam Project, U. S. Forest Service.

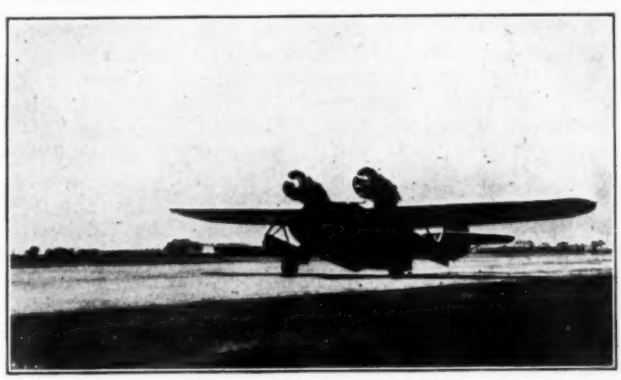


Fig. 12. Runway of Clover Field Airport, California, Soil Stabilized with Bituminous Emulsion.

of moisture may be learned by testing. Such tests were performed on a sample of one of the most troublesome of subgrade soils—due to excessive volume change—the highly tenacious and sticky soil from zone B of the Iredell series.

A sample compacted at optimum moisture content was placed between the dry porous stones in the apparatus and a load applied in increments up to 8.2 tons per square foot. The load was then reduced to 0.05 ton per square foot. Water was then allowed to enter the testing apparatus and after a considerable interval of time the load was again increased to 8.2 tons per square foot and then reduced to 0.05 tons per square foot.

Similar tests were performed on sample of the same soil in dust phase, at optimum moisture content but loose, and on a sample wetted to about the liquid limit. The results in terms of thickness of soil layer per unit thickness of solids in the layer, are shown in Fig. 10. The small change in the thickness of the layer of the densified sample as compared with that of the thicknesses of samples of the same soil in the dust, wet and loose state illustrates the effect of the stabilization process.

Surface Treatments Required On Densified Soils.—The maintenance of high density requires that loss of moisture from the densified soil by evaporation be prevented. This and also the necessity of protecting the densified soil from the abrasive action of traffic requires the use of bituminous surface treatments.

The beneficial effect of such treatment is excellently illustrated by the performance of the blotter-type tar and asphalt surface treatments on the heavy gumbo soils roads of western Minnesota and eastern North Dakota.[16]

Low-Cost All Weather Roads Required in Highway Program.—Substantial progress has been made in the design of soil mixtures, the use of bituminous surface treatments and stabilization of the moisture content by means of treatment with deliquescent substances.

The method of stabilization by densification at optimum moisture content has been utilized principally in connection with the construction of embankments for use as earth dams although it is equally applicable for use in any kind of fill, subgrade or soil base course construction.

Suitable tests are now available for determining the optimum moisture content and the maximum density obtainable with a selected method of compaction; the effect of admixtures and methods of compaction for increasing or decreasing the maximum obtainable density; the resulting consistency of the mixture in both confined and unconfined state; and the presence of detrimental elasticity which would cause the densified material to expand and soften in the presence of water.

Field experimentation in the use of chemical admixtures which do more than stabilize the moisture content include the use of portland cement, bituminous, and the combination treatment of sodium silicate and calcium chloride to produce the calcium silicate precipitate.

Several sections of cement stabilized soil road with bituminous surface treatment were constructed by the South Carolina State Highway Department during 1934. See Fig. 11. Included in the examples in which bituminous emulsion was mixed with the soil is the runway at Clover Field Airport, California, Fig. 12. The use of the silicate-chloride method of treatment has been confined primarily to the stabilization of soil carrying the foundations of piers or buildings and the like.

The stability furnished by compaction of soils at optimum moisture content suggests that vastly greater benefits may be expected when the interfacial colloidal films are stabilized by proper use of bitumen, the portland cement and the sodium, potassium and calcium ions.

New developments can be expected as progress is made in this vast and but little explored field. The materials being investigated are low in cost and widely different in character. They are subjected to varying weather conditions and traffic loads. The results obtained should be evaluated on the basis of the benefit rendered by the stabilizing procedure in comparison with its cost.

More than 2,000,000 miles of road or about 80 per cent of the total rural road mileage is unimproved earth road. On much of this mileage surfacing is not economically justified but there is a considerable mileage which should be surfaced and the extent to which this is done will depend on the cost.

Acknowledgement.—The foregoing is an abstract of a paper presented Feb. 15 at the Annual Convention of the Association of Highway Officials of the North Atlantic States.

[16] "Blotter Treatment of Gravel Roads in the State of Minnesota," by F. C. Lang, Eighth Annual Asphalt Paving Conference, 1929.

▼

Advocates Abandonment New York State Contract Bonds

Colonel Frederick Stuart Greene, New York State Superintendent of Public Works, in a special report to the Legislature, has recommended the complete abolition of state contract bonds. Such bonds are not required on state highway contracts and the result has been a saving of $828,653 since 1923, he pointed out, whereas in the same period it cost the state $2,033,059 for bonds on building contracts.

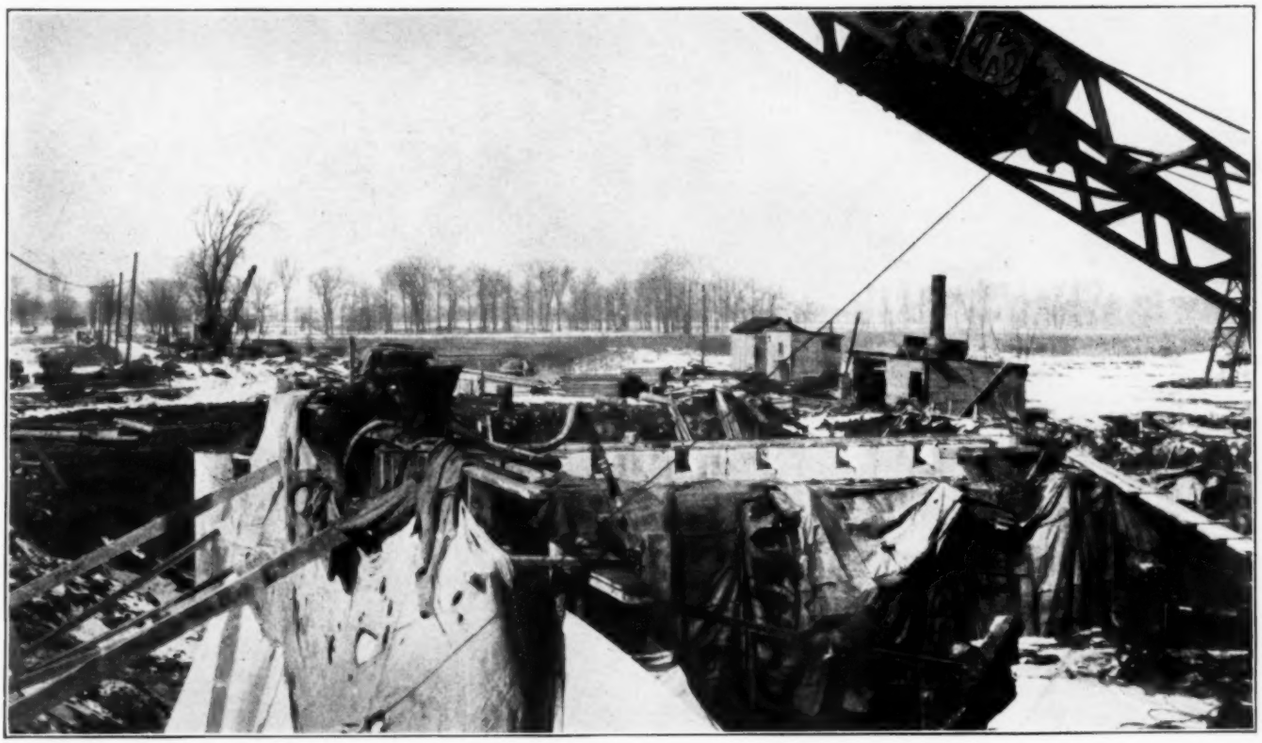
▼

Autos to Use Old Trolley Tunnel in New York City

The old New York City Park Avenue trolley tunnel, through which the Madison Avenue cars used to pass between Thirty-second Street and Forty-second Street is being converted into a vehicular tunnel for automobile passenger traffic. This utilization of the tunnel for vehicles will increase the traffic capacity of Park Avenue below Forty-second Street by adding a new northbound and a new southbound lane, both underground and free of intersections or traffic stops between the end of Fourth Avenue at Thirty-second Street and the mouth of the tunnel in front of Grand Central Station.

Underwood & Underwood News Photo

Trolley Tracks Being Torn Up at 38th St. and Park Ave., New York, to Make Ready for Laying of New Paved Motor Road from 33rd St. to 41st St. on Park Ave.



General View Looking West: Inclosure for Abutment Side Wall in Foreground; Main Abutment Inclosure Farther Back, with Top of East Pier Showing Above It; Heating Plant at Right; Excavating Crane at Work in Left Background; Concrete Hopper at Top of Abutment Side Wall; Electric Generator in Lower Right Hand Corner

WINTER CONSTRUCTION ON A COOK COUNTY BRIDGE

THE accompanying views show construction, March 1, on a new bridge over the Skokie ditch, a mile west of Glencoe, Illinois. The structure is required by two distinct and essentially independent improvements—the widening of Dundee Road and the drainage and development of Skokie marsh under a CCC project.

Dundee Road is an east and west highway, carrying heavy local traffic on a narrow pavement which is to be widened during the coming summer.

Skokie valley, in which these improvements are located, has been for many years a source of both admiration and disgust to residents of Chicago's northern suburbs—admiration for sunsets seen across it, for an interesting and varied bird life, and for a subtle, changing beauty of lights and shadows—disgust as the breeding place of mosquitoes which made outdoor life in the towns intolerable in summer months. Several years ago a mosquitoe abatement district was established, which, by judicious drainage and oil application greatly reduced but did not eradicate the plague.

A considerable part of the valley is in forest preserve, and much of the remainder is unoccupied. Here was established one of the first and most extensive of the CCC projects; and under it, the area is now rapidly being converted into a great playground for Chicago and its near neighbors. Most important in this project is the control of the waters—normal as well as flood—which, coming from as far north as Wisconsin and, in smaller quantities, from the west and the east, flow southerly to the drainage canal and Chicago River.

The old Skokie ditch—until now the only definite channel for this flow—was entirely inadequate, and in

Discharging Concrete Into Hopper on East Abutmen'

each flood season overflowed many square miles in the valley. Stagnant pools left by receding high water, and stagnant places in the ditch itself at low water, furnished the mosquitoe breeding places. These will be eliminated, and the nuisance entirely overcome by the work now in progress. The new channel will be of sufficient cross section to carry all floods, and a continuous flow will be maintained in it even in low water season. It will be enlarged at certain points into a series of lagoons forming units in the stream control system and important features in the landscape development.

Dundee Road is built on a low fill over the valley. It crossed the old ditch on a bridge perhaps 40 ft. long and barely wide enough for two cars, at a point several hundred yards east of the bridge now under construction. The new bridge is to have three 47 ft. spans and a deepened channel.

The contractor moved to the site early in January, but because of cold weather did not push concrete work actively until about Feb. 1. Since then one pier has been completed and one abutment advanced well toward completion. It is expected that the bridge will be finished in May, but the new pavement probably will not be open for use until about Aug. 1.

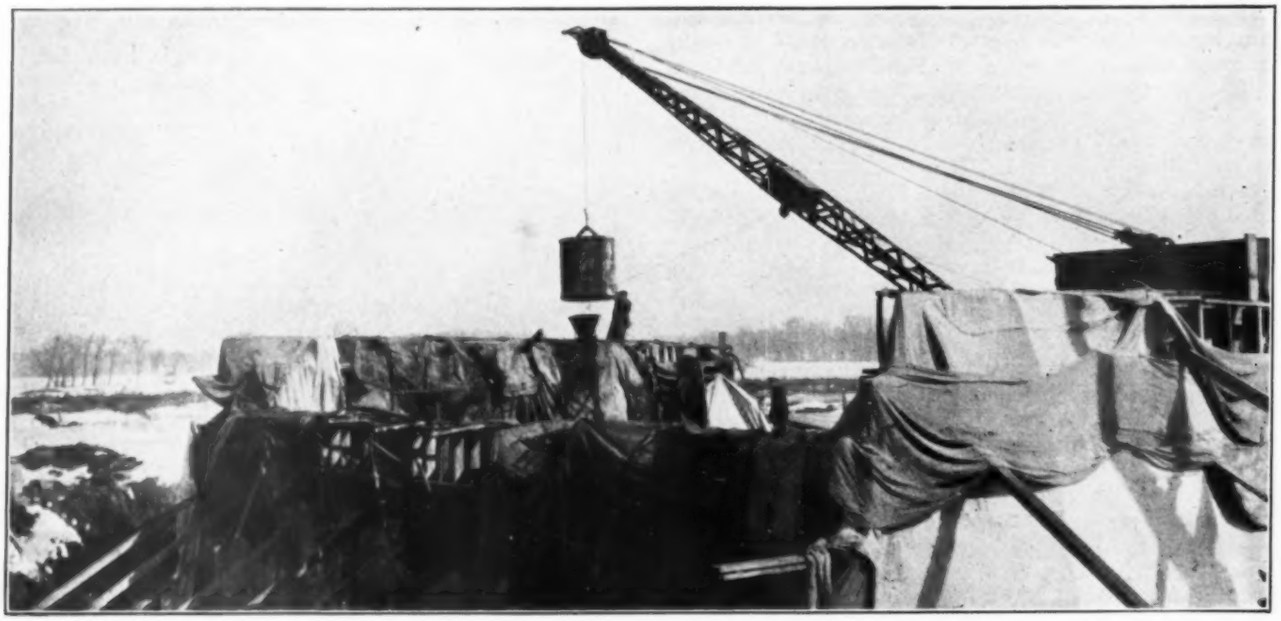
Traffic is carried past the work on temporary fill and pile trestle.

The bridge footings are on wood piles—63 under each pier and 148 under each abutment and its side walls. Piles were driven according to load requirements in the rather soft ground to depths of 20, 25, and 30 ft. below the footings.

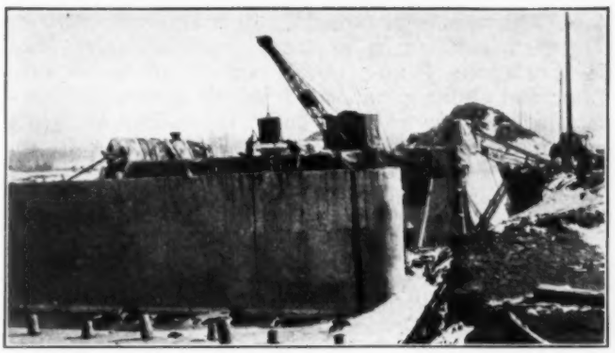
Pier footings are 9 ft. wide by 3 ft. thick. Above the footings the pier width is 4 ft. 9 in. for the entire height except for the top 2 ft., where there is a slight batter. Length of piers is 64 ft.—of abutments 62 ft. Abutment side walls are 27 in. wide at the bottom and 12 in. at top.

The concrete mix is determined by water-cement ratio according to State specifications. An outside temperature of 18° F. above zero was the lowest at which concrete was poured. Temperatures inside the inclosures were not allowed to drop below 70° F. Heat is supplied by steam at 80 lb. pressure from a boiler in a centrally located shanty. Aggregates are steam heated before charging, and an oil flame is maintained in the mixer—a Koehring 2-bag "Dandie."

Inclosure of South Wall of East Abutment, with Concrete Hopper and Steam Pipes. Top of East Pier Shown at Right.



General View of East Abutment Inclosures. Concrete Bucket Over North Side Wall



Completed East Pier with East Abutment Behind It. Concrete Mixer Behind Pole at Right. Concrete Bucket Being Swung Over Hopper on Abutment Wall. Piles in Foreground Are to Carry Falsework for Superstructure of Middle Span

Concrete is handled in a ¾ yd. bucket by a Koehring crane, about 10 yd. per hour being placed with this combination. Photographs show the bucket discharging into chutes on the east abutment.

All concrete is vibrated with a Jackson vibrator. The contractor generates lighting current with a small D.C. unit, to which has been added a convertor to supply the alternating current necessary for the vibrator.

Foundation pits have been kept clear of water by two truck-mounted pumps. The water problem is less serious during the winter season than it would be in spring or fall. Excavation is by crane and drag line.

The form crew consists of 6 carpenters and 4 laborers. There are about 12 men in the mixer crew. All work is under NRA rules.

The job is being done for Cook County by the Arcole Construction Company of Niles Center, Illinois.

Compacting Concrete By Vibration

PLACING concrete mixtures with vibratory equipment is a comparatively recent development, although, as in the case of joints, the principle is not new and was tried experimentally on laboratory specimens more than a decade ago. The successful placing of mixture by vibration under actual construction conditions, however, has depended upon the development of proper equipment with which to perform the operation satisfactorily. Some interesting information on this subject was given by V. L. Glover, Engineer of Materials, Illinois Division of Highways, in a paper presented at the 1935 Purdue Road School, from which the matter following is taken.

The compaction of concrete in structures by vibration is at present required in many states; the compaction of pavement concrete by means of finishing machines equipped with vibratory screeds is, so far as known, required in only one state. Illinois requires vibration of concrete in all structures having a span of 20 ft. or more. For smaller structures, hand and vibratory methods are optional with the contractor.

Experiences in Illinois.—One season's construction has been completed under these specifications, and while a complete study has not been made of the data obtained, it is felt that vibration is far superior to hand methods in consolidating the concrete.

The selection of concrete mixtures for use with the vibratory equipment has been characterized by a certain conservatism. It is quite possible that the full benefit in saving of cement without reduction in quality of concrete has not been realized through the use of the vibratory equipment. It is felt, however, that conservatism is desirable so long as the method of procedure is experimental or semi-experimental, especially since the concrete in test specimens cannot be vibrated in the same manner as that in structures.

On the average, therefore, the weight of sand per bag of cement has been kept about the same and the amount of mixing water about the same or a little less than when hand methods are used, whereas the amount of course aggregate has been increased to conform with the ability of the equipment to place the mixture. The consistency of the concrete was varied to suit the particular condition, the slump ranging from 1 to 4 in. with an average of 2½ in. Probably the saving in cement did not exceed ¼ bag per cubic yard of concrete.

Under these conditions it would be expected that the quality of the concrete obtained would be at least as good as that obtained by hand methods. That the consolidation obtained was better could be seen both by observation of the placing of the concrete and from the appearance of the finished product.

Tightness of forms is much more important than when hand methods are used. Any opening will cause leakage of mortar from around the coarse aggregate, resulting in a small area of honeycombed concrete at such point. Small air bubbles between the form and the mass of concrete which mar the appearance somewhat seem to be a natural consequence of this method of placing, but these have not presented any particular problem. A large percentage of these may be removed on exposed surfaces by rubbing.

The rapidity with which vibratory methods of placing concrete in structures have been accepted by engineers and contractors alike indicates that the method is not only sound from an engineering standpoint, but that it is equally justifiable from the standpoint of savings in the cost of construction operations.

Vibratory Methods in Placing Concrete Pavement.—The use of vibratory methods of placing concrete pavements has not received the universal acceptance accorded the internal vibration employed for structures. Since a pavement is relatively thin, internal vibration is rather impractical except where it may be used to advantage in consolidating the concrete at localized points, such as at expansion and contraction joints, adjacent to the longitudinal point, and along the forms. The vibratory units are in general placed on top of the screeds, imparting to these the properties of both screeding and vibrating simultaneously.

Although development of other types of vibrating units has been reported, the vibration used in placing concrete pavement up to the present time must in general be classed as external vibration, it being applied to the surface of the mass and not to its interior.

The advantages which result from external vibration in placing concrete pavement are well known. Since drier consistencies may be used, either the water-cement ratio may be decreased, resulting in higher strength concrete; or the amounts of aggregate may be increased, resulting in a saving of cement; or a middle course, that of decreasing the water-cement ratio and increasing the amounts of aggregate simultaneously but to lesser degrees, may be followed, resulting in both increased

strength and saving of cement. This not only follows from the fundamental principles of design of concrete mixtures, but has also been shown through investigation performed by three or four states to study the merits of this method.

Illinois Tests.—Illinois undertook an investigation during the month of August 1932 and included the construction of about one mile of pavement, consisting of 114 individual sections and nearly as many different mixtures, duplications being made in a few instances. Both gravel and crushed stone coarse aggregates were used. The finishing machine was essentially a standard type with the screeds designed in a slightly different manner. Three vibratory units, which operated at about 3,600 impulses per minute, where placed on the front screed and two on the rear screed.

The design of the mixtures was varied to show not only the most suitable proportions but also the limitations of the equipment. The quantities of aggregates per bag of cement were varied approximately from 180 to 265 lb. of sand; from 320 to 510 lb. of crushed stone; and from 360 to 540 lb. of gravel, the larger quantities of sand in general corresponding to the larger quantities of coarse aggregate. The cement content was varied approximately from 1.1 to 1.5 bbl. per cubic yard of concrete. The amount of mixing water for standard strength was in the vicinity of 5.33 gal. per bag of cement, but had to be increased for several of the harsher mixtures in order to place these satisfactorily.

It was found that standard strength was in general obtained where the mixing water was not increased above the specified amount, and that satisfactory consolidation of the concrete was obtained in all instances. The most suitable mixtures were of about ½ in. slump and contained a ratio of sand to total quantities of aggregates of 32 to 35 per cent. A reduction of about 15 per cent from the amount of cement used with ordinary equipment was obtained without sacrifice in quality of the concrete.

▼

Cleaning Painted Guard Rails

The Maintenance Bureau of the State Highway Department of Washington is using a vapor spray method of cleaning painted highway guard rails, by means of which, it is reported, at least one painting operation per year is saved.

The illustration shows the cleaning operation in progress. The equipment consisting of a Hypressure Jenny Cleaner, manufactured by the Homestead Valve Mfg. Co., Coraopolis, Penn., 600 bbl. water tank, motor generator and cleaning compound barrels is mounted on a state highway truck. Two outlet vapor lines are piped from the cleaner; one extending to the front of the truck; the other to the rear. To each of these lines is attached a 25 ft. length of hose with a single gun and a 2 in. flat nozzle. The man at the front of the truck with control valve on the gun half open, cleans the posts and keeps the guard rail thoroughly wet. The man at the rear using full pressure cleans the rail thoroughly.

Cleaning Guard Rail on Washington State Highway

In addition to the cleaning of guard rails, the department uses this equipment to clean bridges, abutments, over-passes and center lines as well as keeping their entire construction equipment cleaned. The latter operation is done at district highway maintenance headquarters.

▼

Grade Crossing Work in New York

The New York Central Railroad has been ordered by the Public Service Commission to explain why it has not begun work on 19 grade crossing projects in New York State. The crossings involved include: North Main Street, Pawling, Dutchess County; Montrose-Courtland, Westchester County, and Hawthorne and Cross Streets, Mount Pleasant, Westchester County.

▼

Nature Trail for New York City

Construction of a nature trail for New York City has been announced by the park department. The trail, to be the first of its kind in the city limits, will be in Alley Pond Park, Douglaston, Queens. Work will be started as soon as the ground has thawed. It will be 1½ miles long and will include geological and biological points of interest as well as horticultural. Every effort will be made to subordinate the work of man to nature. No park benches but huge logs from fallen trees will provide informal resting places.

▼

U. S. to Alaska Highway

The Senate passed and sent to the House the McNary bill, February 25, 1935, to authorize negotiations with Canada for construction of a highway from the United States to Alaska. The bill would ask President Roosevelt to negotiate with Canada to construct its portion of the highway. It also would authorize appropriations of $1,000,000 for the negotiations and plans and $2,000,000 for construction of the road in Alaska.

▼

New York to Widen 3,700 Miles of Road

Immediate widening of nearly 3,700 miles of New York State's highway has been recommended by Capt. Arthur W. Brandt, the Commissioner of Highway, in his annual report to Gov. Lehman and the Legislature. Capt. Brandt said that the 16-ft. roads should be widened to 20 ft. The cost, based on $6,000 per mile, would be more than $22,000,000.

Much of this mileage, Capt. Brandt states, is on the secondary system and its widening can be delayed for some years. However, the narrow mileage on the primary system should be progressed as rapidly as funds will permit. Without question, many accidents are due to the narrowness of the pavement.

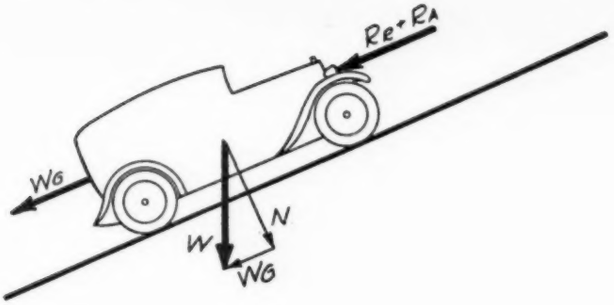


Fig. 1—Diagram of Forces Acting on a Car Traveling Up a Grade at Uniform Speed

AUTOMOBILE POWER EXPENDITURE AS AFFECTED BY ROAD GRADE

THE effect of grades on power requirements and gasoline consumption was the subject of studies by the Iowa Engineering Experiment Station as a part of a general study of tractive resistance. Elaborate tests were made over a period of 3 years, and important practical conclusions reached. The first section of a condensed account of the tests and results relating to character of road surface was given in the December issue of ROADS AND STREETS; the remainder of the article appears in this issue. The studies on grades, which likewise are of much importance, are quoted here, with slight omissions, from the full account as given in Bulletin 119 of the Iowa Engineering Experiment Station, Iowa State College, Ames, Iowa. R. G. Paustian, Instructor of Civil Engineering, is the author. The bulletin's title is "Tractive Resistance as Related to Roadway Surfaces and Motor Vehicle Operation." It is dated August 1, 1934.

All of the studies were made with a single test car—a Model 314 Cadillac coach, especially equipped with a gas-electric drive to provide an accurate basis for measurements. This car, its instrument-board, auxiliary devices, and method of operation were briefly described in the article in December ROADS AND STREETS. Power control was through the throttle of the gasoline engine, which was directly connected to the electric generator from which power was supplied to the motor driving the rear wheels.

The experiments included important studies of air resistance.

The following definitions are used:

Tractive Resistance.—A hypothetical force whose line of action is parallel to the road surface and the longitudinal axis of the vehicle, and whose magnitude is equal to the summation of the components in that line of all external forces acting on the vehicle when it is traveling on a level road surface.

Rolling Resistance.—That part of tractive resistance due to the resistances in the running gears and tires of the vehicle and the deformation and irregularity of the road surface.

Grade Resistance.—The component of the weight of the vehicle down the grade.

Driveshaft Horsepower.—The actual amount of power transmitted to the shaft which drives the rear wheels of the car.

Quoting directly from the bulletin:

"When a motor vehicle is ascending a grade, it is resisted by forces noted as rolling resistance, air resistance,

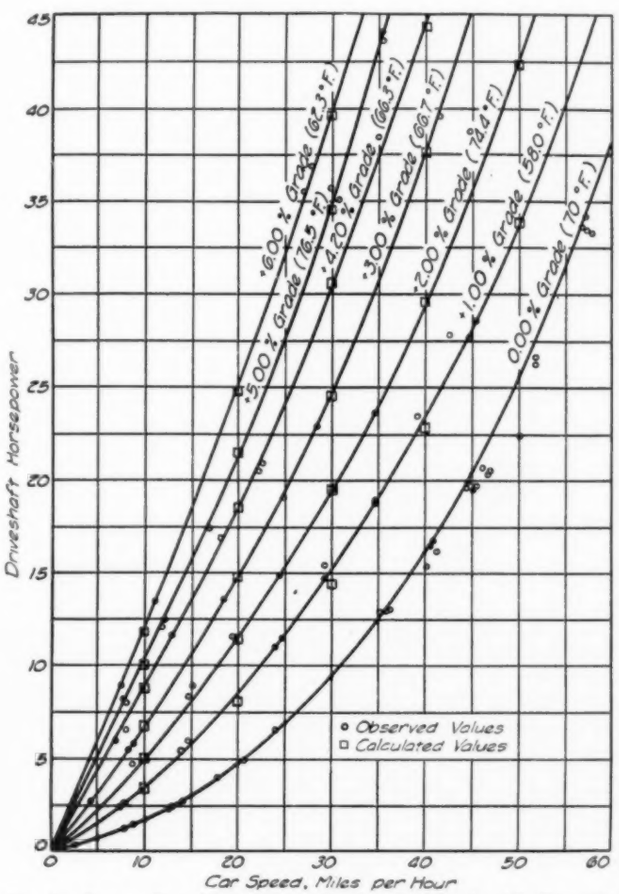


Fig. 2—Power Requirements on Grades Surfaced with Concrete

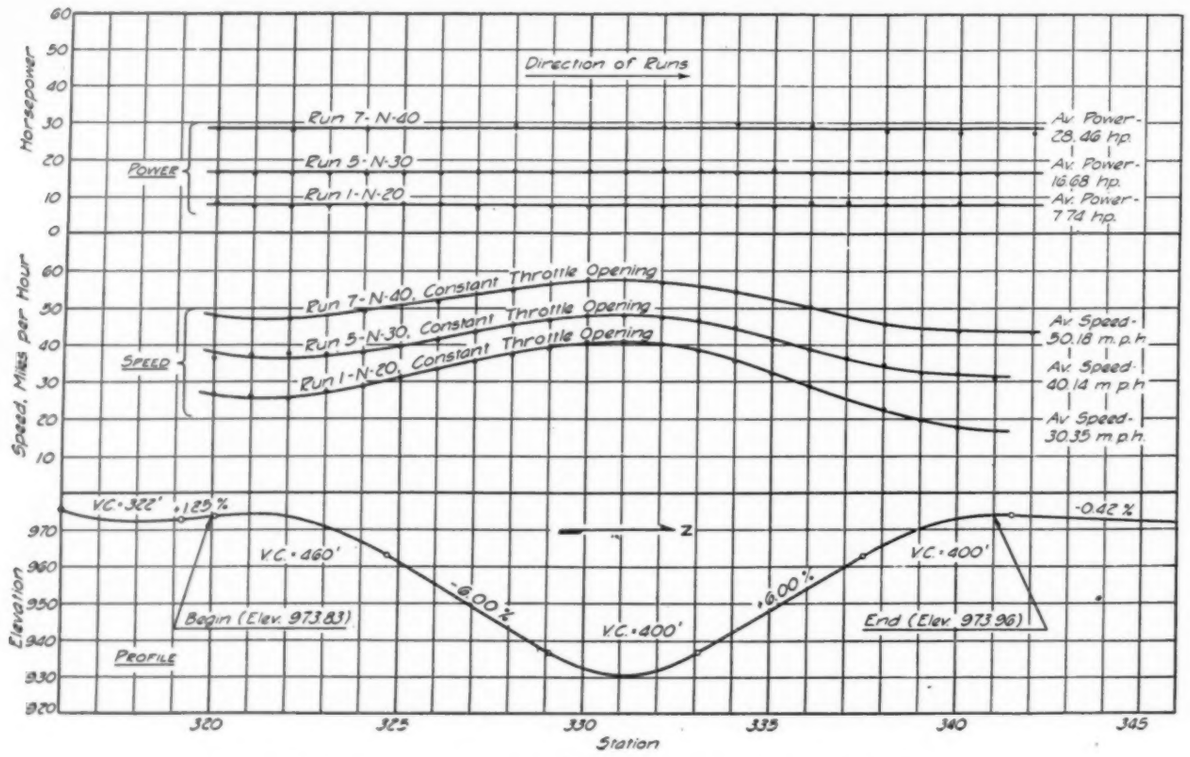


Fig. 4—Energy Consumption on Rolling Grades at Constant Throttle Opening

and grade resistance. The first two, rolling resistance and air resistance, have been discussed and typical values given for level road surfaces. Grade resistance is due to the component of the weight of the vehicle acting down the grade and may readily be shown to be equal to $20G$ pounds per ton of vehicle weight, if G = the percentage of grade (Fig. 1).

"Values of grade resistance for various rates of grade can be calculated, and, if added to values of rolling plus air resistance on a level surface, will give values of total resistance on grades. If so desired, the power required to overcome this resistance can be calculated by using the formula,

$$P = R_T V / 375.*$$

"The power required in ascending grades of 1 to 6 per cent is shown in Fig. 2; Fig. 3 shows the gasoline used in generating this power. In the latter diagram there seems to be a definite relation between the rate of grade and the speed at which maximum mileage per gallon of gasoline is secured. This trend is indicated by the dotted line in the figure.

"The curves of Fig. 2 show the horsepower (electrical energy), as measured at the driveshaft, used in ascending the grades indicated. The exceedingly close agreement between the measured and calculated values of total resistance is not only an indication of the degree of accuracy attained in the investigation, but also additional proof of the probable correctness of the values of rolling plus air resistance on a level road surface.

Rolling Grades.—"The tests just described were made at uniform speeds on individual grades and, as such, include no effects due to momentum that may occur when a vehicle is driven over a course whose profile is a series of ascending and descending grades. It may be enough to know the power required and gasoline used on level roads and on various individual grades, but in order to be comparable with ordinary driving practice, tests should be made over roads having 'rolling' grades. In so far as previous experiments are concerned, such test data are scarce, due probably to the difficulties encountered in recording the changes in performance of a motor vehicle as it travels uphill and downhill."

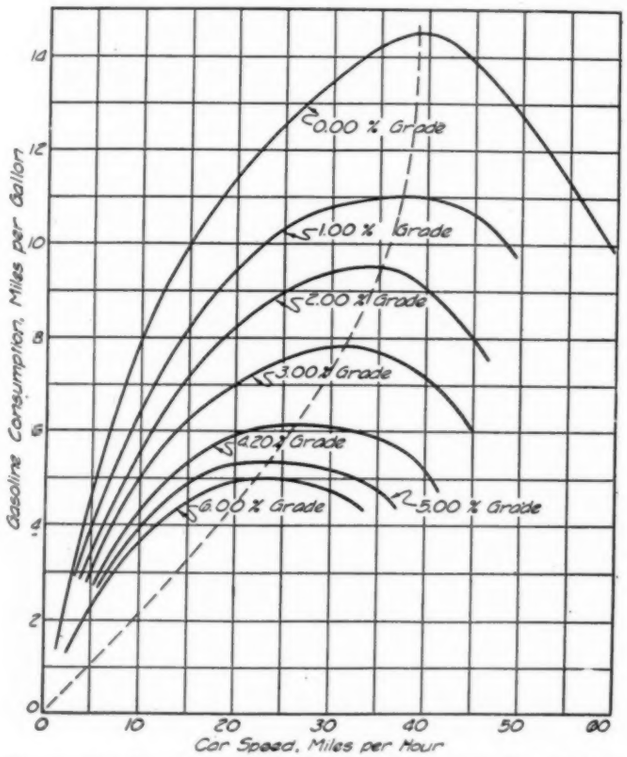


Fig. 3—Gasoline Consumption of Test Car Ascending Grades Surfaced with Concrete

*In which R_t = total resistance to motion of the vehicle in pounds, P = horsepower required to overcome R_t, and V = vehicle speed in miles per hour.

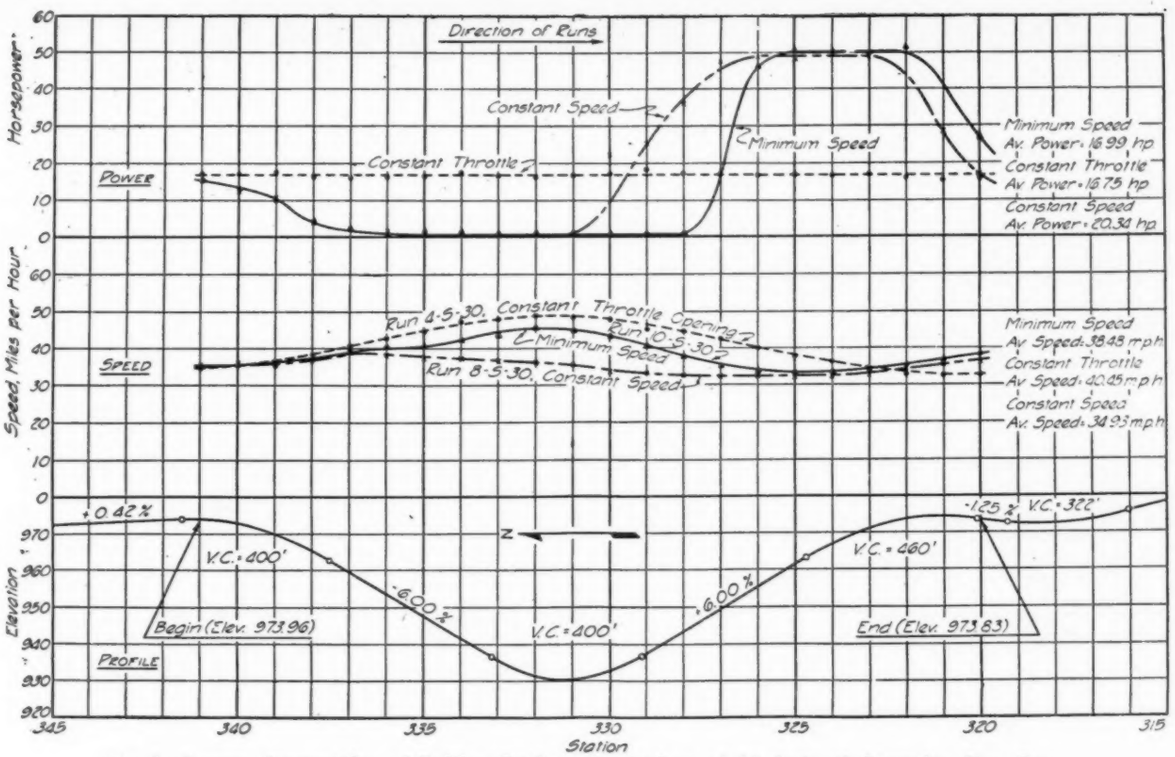


Fig. 5—Energy Consumption of Rolling Grades; Comparison of Methods of Operating Test Car

Three Ways of Driving on Grades.—"There are three distinct ways of operating an automobile over a road having a rolling grade line: (1) At constant throttle opening, allowing the automobile to speed up when going downgrade and slow down when traveling upgrade; (2) at constant speed, braking when this speed is exceeded, and throttling when the speed begins to drop, and (3) at what might be termed a 'minimum' speed; that it, allowing the automobile to coast downgrade and up the ascending grade until the desired speed is reached and then maintaining that speed through the balance of the ascending grade. In the present investigation, the majority of tests were made at constant throttle opening. A number of tests, however, were made at constant speed

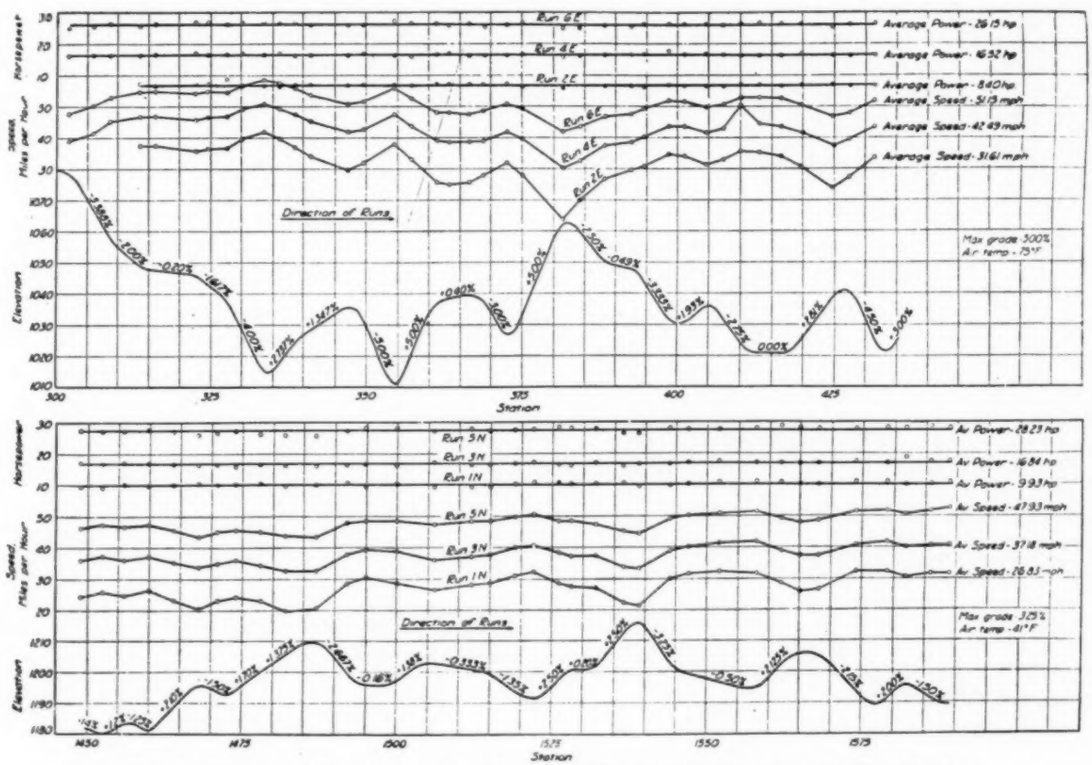


Fig. 6—Power and Speed Curves for Constant Throttle Operation Over Rolling Grades

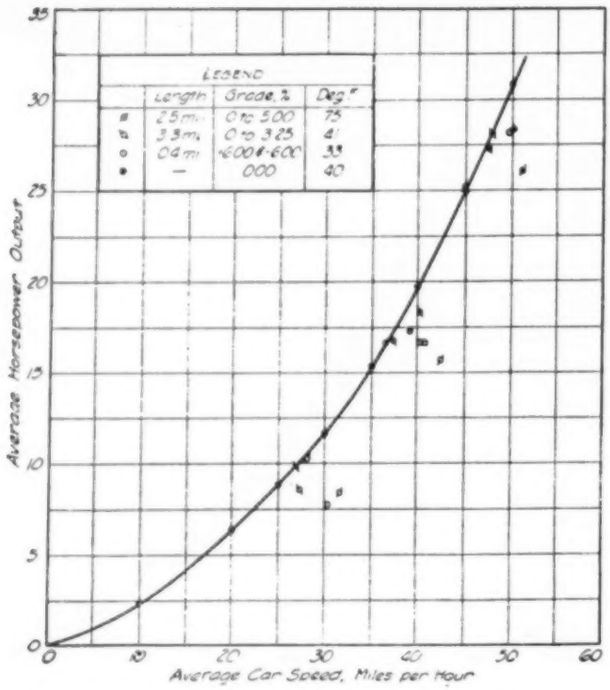

LEGEND
Length | Grade,% | Deg F
2.5 mi | 0 to 5.00 | 75
3.3 mi | 0 to 3.25 | 41
.04 mi | -6.00 to -6.00 | 33
— | 000 | 40
Average Horsepower Output
Average Car Speed, Miles per Hour

Fig. 7—Comparison of Power Requirements on Road Surfaces Having Flat and Rolling Grade Lines

and minimum speed (Figs. 4 and 5). These diagrams indicate the relation between power output, speed, and the road profile under each of these operating conditions.

"The curves of Fig. 4 are plotted from the results of 'north' runs at constant throttle opening. Run I-N-20 was made with the throttle set at the opening required to maintain a speed of 24 miles per hour on a level surface; runs 5-N-30 and 7-N-40 are for speeds of 35 and 46 miles per hour, respectively, on level surfaces. The results of these tests over the plus and minus grade indicate a definite increase in speed with these throttle openings, the average speeds being 30.35, 40.14, and 50.18 miles per hour as compared with 24, 35, and 46 miles per hour on a level surface.

"Another fact noted is that, with constant throttle opening and with the speed allowed to fluctuate freely, there is practically no variation in the amount of power used. In other words, constant throttle opening is accompanied by constant power output, regardless of the road profile. This observation has been checked by the results of tests over courses up to 3.5 miles in length.

"The relationships between the power output, car speed, and the road profile are illustrated in Fig. 6. These diagrams are the results of tests made at constant throttle opening over courses 3 to 4 miles in length. The upper diagram in Fig. 6 gives the curves for tests made over a course wherein the maximum grade plus or minus, did not exceed 5 per cent. The maximum grade for the road profile shown in the lower diagram in Fig. 6 was 3.25 per cent. As stated, these tests check the observation that constant throttle opening is co-existent with constant power output.

Varying Speed Saves Gasoline—"Probably the most important result of these constant throttle runs is shown in Fig. 7, where the results of all of the foregoing series of tests are compared with those of tests on a level road surface. A comparison of the values given by the power curve for a 0.0-per cent grade and the points plotted as a result of the tests on grades clearly indicates that, with constant throttle opening, the average power output on the rolling grade at a certain average speed is less than that required to drive the car over a level road surface at the same speed. With this test car on rolling grades, any type of operation other than constant throttle required average power outputs greater than those required on level road surfaces. As far as power requirements are concerned, these tests indicate that the most economical manner of operating the vehicle in question is at constant throttle.

"The gasoline consumption records for the foregoing tests have also been plotted to be comparable with those for a level surface, with the result indicated in Fig. 8. It can be said that not more fuel is used in traveling over the rolling grades than on a level surface and there seems to be sufficient data to indicate that even less is used in certain cases.

"At this point it is well to recall that the test car was constructed so that it "free wheeled" on grades. There was no mechanical connection between the rear wheels and the gasoline engine. Therefore, when the car coasted down a grade there was no braking effect from the engine

"The foregoing observations are of importance in the present study because they clearly show the logic of using the results of tests on level road surfaces as the basis for determining the differentials in the cost of operating an automobile on various types of road surfaces. They are of further significance because they bring out the fact that there is some relationship between highway grades and motor vehicle operating costs. At the most it is certain that additional research is necessary to establish those relationships."

While grade problems are obviously less important in highway than in railway location, they are still worthy of consideration, and it is to be hoped that additional studies will be made in the near future to show more closely the relationship between grades and automobile power requirements.

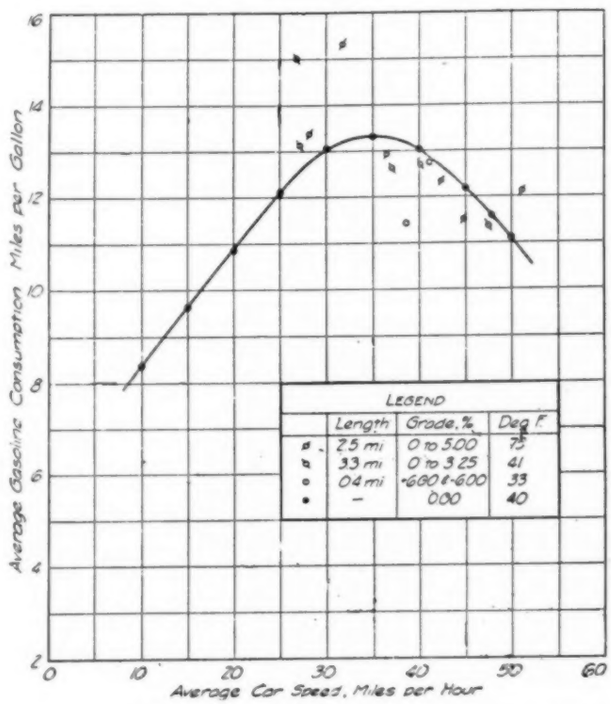

LEGEND
Length | Grade,% | Deg F
2.5 mi | 0 to 5.00 | 75
3.3 mi | 0 to 3.25 | 41
.04 mi | -6.00 to -6.00 | 33
— | 000 | 40
Average Gasoline Consumption, Miles per Gallon
Average Car Speed, Miles per Hour

Fig. 8—Comparison of Gasoline Consumption on Roads Having Flat and Rolling Grade Lines

OIL-MIX ROADS IN UTAH

By E. C. KNOWLTON
Assistant Chief Engineer,
Utah State Road Commission

AFTER experimenting with the close graded road mix type and the open graded surface treatment type during the season of 1927, Utah adopted as standard the close graded method, as has all the other mountain states.

Construction Policies in Utah.—In the beginning Utah adopted and since has retained 3 in. as the standard thickness for the oil layer. Some of the sister states first tried thinner oil surfaces but, as a general thing, this dimension is now used by all. Inasmuch as the previously built gravel roads in Utah provided but 18 ft. as width of surface, this was the standard for a few years after we began oil treatments. About three years ago, and rather belated, a 20 ft. width was adopted for all main roads. For the earlier work a minimum of 3 in. of gravel subbase was used under the oil layer, which has proved to be adequate only where drainage and soil conditions are satisfactory. As will be explained later, these gravel foundations have been gradually increased in thickness.

The circumstances surrounding the advent of the oil road culminated so rapidly that due to the experimentation necessary, standardized specifications were out of the question; and so long as methods were uncertain, contractors could not be expected to buy expensive equipment to prepare themselves for this work. Consequently, initial oil construction work in Utah, and in most of the surrounding states, was done by state forces.

Mileage of Oil Roads Constructed in Utah.—In 1927, the first year, there was constructed by state forces, a total of 30 miles; and similarly in 1928, 70 miles. During 1929, 55 miles were built by the contract method and 70 miles by state forces. In 1930, 115 miles were constructed nearly all by contract, and beginning with 1931 all were contracted; the work of that year being 245 miles, with 240 miles in 1932 and 190 miles in 1933; giving a total in excess of 1,000 miles at the beginning of this year. During 1934 the program includes 224 miles. Almost every mile included in the above is in use today. There have been some complete failures, but all have been short sections, seldom over a mile or so in length, these being located invariably over low, poorly drained soils.

Detailed Construction Methods.—For purposes of explanation the evolution in methods of construction will be divided into two periods; 1927 to 1931 inclusive, and 1932 to 1934 inclusive. During the first period the standard methods were as follows: Roads to be oiled during any season were examined well in advance of construction, by digging frequent test holes to obtain thickness of existing gravel. Additional gravel of proper quality for oiling was then added to bring the total compacted thickness to a minimum of 6 in., with greater amounts placed over sections of doubtful stability.

The oiling process began by first scarifying the surface to a depth insuring 3 in. after compaction, and then shaping to proper cross section. Oil was applied in three applications, the total amount used averaging 2 gal. per square yards of road surface. After each application, partial mixing by means of harrows was required, and following the last application the material was bladed into a windrow in the center of the road. Samples of the mix were then obtained for field laboratory tests to determine if the proper proportion of oil and gravel had been obtained. If not, additional oil was added or more gravel scarified from the road surface. The partially mixed material was then bladed back and forth across the road, by means of blade graders, until all particles were coated with oil and a uniform color was obtained. Laboratory tests were again made of the completely mixed material. It was then spread to proper cross section and carefully maintained by dragging under traffic until the surface was compacted.

The second period, 1932-1934 is characterized by improvements in type of construction, which have materially improved the standard of the oil road with corresponding increases in cost. These improvements are the results of the common experiences of the mountain states and their adoption has been encouraged, and indeed, made possible by the increased emergency Federal aid highway funds made available to the states as part of the relief program.

The widening to 20 ft. of the oil surface was adopted in Utah during the latter part of the first period, this obviously increased the amount and cost of labor and materials nearly 10 per cent. The next change was the rolling of the oil surface with a power roller, to be followed by a surface treatment called, the "seal coat." Previously the surface was allowed to compact under traffic. The roller accelerates the compacting process, resulting in a smoother surface and more dense oil layer. The seal coat treatment consists of the application upon the rolled and compacted surface of a light application of a medium curing cutback asphalt. Upon this is immediately spread a layer of cover material sized to minus ½ in., with much of the sand removed. This is applied at the rate of about 150 tons per mile. This surface treatment has more than justified its cost of about $500 per mile. Before its use the oil mix, in order to be protected against weather and traffic, of necessity contained the maximum amount of oil consistent with stability; and it is these richer mixtures which are more vulnerable to damaging water action. The seal coat permits of a less amount of oil in the mix itself thus increasing stability and also supplies a tougher more impervious wearing surface, which seals the surface voids, and prevents raveling caused by traffic, and the deteriorating forces of the weather; also furnishes a more non-skid surface.

During this same period on the main roads gravel bases were reinforced from a 3 in. minimum to a 6 in. minimum, which has added about 3,000 tons of gravel per mile to the work. This subbase gravel cannot properly be chargeable to the oil surface as it becomes a part of the permanent road investment regardless of the surface which might be applied.

Improvement in Construction Methods.—Beginning with 1933 in Utah, new departures as to methods of construction are being adopted. Two types of mixing machines are coming into extended use: One is the stationary plant usually set up at the materials deposit, and used in connection with the ordinary crushing and screening plant; the other is a portable or traveler type of machine operated on the road.

Oil-Mix Construction on Cisco-Colorado Line Highway in Grana County, Utah. Unoiled Gravel Windrow Shows Ahead of Machine and Oiled Gravel After Passing Through Machine at Rear

The former method, commonly known as "plant mix," includes the following procedure: Upon the prepared gravel road on which the specified amount of reinforcing gravel has been placed, and far enough in advance to permit of proper compacting, there is applied a penetration or tack coat application of medium curing cutback asphalt. When this has dried the surface is ready for the placing of the mixed material. The gravel material is first carefully tested for determining proper proportions of oil, and both materials are conveyed into the mixing plant, where after being thoroughly mixed, are conveyed to the road by trucks, dumped, and spread by blade graders. The previously mentioned rolling and seal coat treatment is then applied. This method has the advantage of better laboratory control over materials and minimum inconvenience to traffic on the road.

With the traveler type of machine the requisite amount of gravel both for foundation and oil layer, as with other road mix methods, is first provided. The surface is then scarified to obtain sufficient gravel for mixing, and by means of blade graders a windrow is carefully made on the outside half of the roadway. The remaining half is carefully prepared and given a tack coat of cutback asphalt to serve as the foundation for the oil layer. Tests are then made of the material in the windrow in the usual way for purposes of calculating the amount of oil. As the machine moves slowly along the road, the mixed material is deposited into a windrow on the side of the road which has been previously sprayed with oil. The other half of the road is then given a tack coat application and after it has dried, the windrow is spread and the rolling and seal coat application follow in due course.

Types of Road Oil.—In 1927 our specifications provided for a 55-65 per cent asphaltic residue with rather low viscosity. For the 1929 work, a 65-70 per cent asphaltic content was required with Seybolt Furol viscosities at 122° F. of 150-300 seconds. The tendency toward higher viscosity oils continued. In 1930 and 1931 we stipulated 65-75 per cent asphaltic content with viscosity at same temperature of 200-350 seconds; in 1932, 70-80 per cent asphaltic content and 275-400 seconds viscosity.

Beginning in 1933, in common with the other western states, standard specifications for the various types of oil and cutback asphalt were adopted for the eleven western states. These standards were the result of several conferences between representatives of the various oil companies involved, together with engineers of these states and the Bureau of Public Roads. Standardization has avoided much confusion; has been of tremendous value to the companies, and is proving very satisfactory to all concerned. The Utah requirements for road oil products of stipulated quality have always been satisfied with a minimum of trouble. The present practice provides for either SC-2 or SC-3 road oil for road mix, or MC-4 cutback asphalt for our plant mixes. There is a tendency toward an increased use of cutback asphalt. Some of the oil projects have been constructed in excess of 100 miles from the nearest rail points, requiring truck haul on oil for that distance.

Construction Costs.—During the period 1927-31, the average total cost of the oil road was $4,000 per mile including $800 for foundation gravel, $1,200 for the gravel for oil layer and $2,000 for oil and mixing, $1,000 of which represented cost of oil on cars at nearest shipping point. For the years 1932, 1933 and 1934, for mixed on the road methods, the total average cost was $6,000 per mile, which represented $2,200 for additional gravel for subbase, $1,200 for the gravel to be oiled, and $2,600 for oil and mixing, including the seal coat. Where cutback asphalt is used, the cost over road oil is increased about $750 per mile and plant mix work is now costing us at least $1,000 per mile additional over mixed on the road methods either by traveler machine or blade graders. The plant mix cutback asphalt combination, therefore, has been costing in excess of $7,000 per mile of which about $5,000 is the total cost of the oil layer, the remainder representing the cost of subbase gravel. It is expected that the difference now existing in cost between the stationary plant and traveler machine methods will in the future be greatly reduced. Necessary grading costs and other incidentals have not been included in the above figures.

Laboratory Control of Materials.—The methods now being used in Utah are as follows: Months before a gravel material is to be used in oiling work, large size samples are submitted to the main laboratory for a series of exhaustive tests. The material as it comes from the deposit is first crushed to the same maximum size, duplicating field conditions.

That part below a ten mesh sieve is segregated out

Oiled Gravel Windrow in Center of Road Previous to Spreading on Cisco-Colorado Line Highway

and given linear shrinkage and field moisture equivalent tests. The effect of water on these fines is very important and some materials are encountered which must be rejected on account of unfavorable qualities as shown by these tests.

A sieve analysis is next made obtaining proportions of the following sizes 1 in. round, ¾ in., ½, in., ¼ in. square; and No. 10, No. 20, No. 40, No. 80, No. 100 and No. 200 mesh sieves. To obtain the proper proportion of oil these results are put in the formula:

$$p = .009A + .02B + .03C + .05D + .068E + .08F + .195G + H.$$

p = percentage of oil.
A = percentage of aggregate larger than No. 10 mesh.
B = percentage passing 10 mesh and retained on 20 mesh.
C = percentage passing 20 mesh and retained on 40 mesh.
D = percentage passing 40 mesh and retained on 80 mesh.
E = percentage passing 80 mesh and retained on 100 mesh.
F = percentage passing 100 mesh and retained on 200 mesh.
G = percentage passing 200 mesh.
H = Absorption factor. Total absorption—% water in field aggregate.

The absorption factor is obtained as follows: The arbitrary assumption is made, and has been borne out closely enough by experience, that the completely dried out material will absorb within its pores as much water in 5 hours as it will oil under road conditions. Sizes from each of the above screens and sieves, except that passing No. 200 mesh are treated separately, each being thoroughly dried then immersed in water for the 5-hour period; then merely surface dried. The total percentage gain in weight of the various portions plus the proportionate increase for the No. 200 mesh material represents the absorption factor. Later, during construction, the percentage of moisture still retained in the material, after the drying operations of the mixing process and which might be termed the feasible minimum of moisture, has been determined; this amount is deducted from the laboratory absorption factor. Materials requiring as high as 2 per cent for the absorption factor have been encountered.

The laboratory predetermination work also includes the actual preparation of mixed samples, in accordance with the formula, and the subjecting of them, as far as is practicable, to field conditions. A trial mixture is placed in an oven at 120° F. for 30 days, during which time it is examined carefully to see if all particles of material are coated with oil. Then the sample is placed as a section of a miniature circular track over which an automobile wheel is propelled. This test demonstrates the ability of the material to compact under traffic. The complete laboratory history for each material is later submitted to the field for guidance during construction. Complete field laboratories are supplied each job. Field sieve analyses are constantly taken in order to adjust the quantity of oil consistent with the varying conditions actually met. By means of "Rotorex" machines, extraction tests are run to determine if the computed amounts of oil are actually being realized. The control methods, in addition to being very positive in results, reduce to a minimum the interference with the progress of construction. It might be interesting to point out that on a typical traveler type mixing machine job of 65 miles constructed this year, the predetermined amounts of oil were sufficiently accurate to require no changes during construction.

The foregoing is an abstract of a paper presented at the 4th National Road Oil Congress.

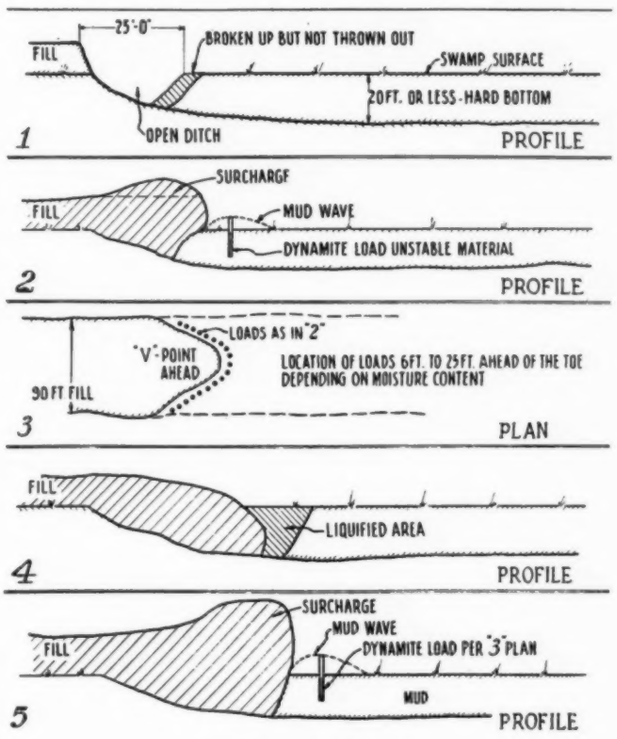
▼

Toe Shooting Method of Settling Fills

To the three older established methods of settling fills with explosives—the "Trench Shooting Method," "Underfill Method," and "Relief Method"—a fourth, the "Toe Shooting Method," has recently been added. It is esentially a combination of the other three methods, and is applicable where the road is built over a new right-of-way, and where the muck is not more than 20 ft. deep. It is described as follows by Mr. L. F. Livingston of E. I. du Pont de Nemours & Co.

If there is a heavy mat, this should be broken up with a minimum of explosives by propagation ditch shooting. The balance of the operation is best understood by referring to the diagrams:

Fig. 1.—Shows the start of the fill into the swamp.



Toe Shooting Method

An open ditch is shot for the width of the road, and to a depth of 4 to 6 ft. The fill is carried forward as in Fig. 2 until a sizable mud wave is pushed up—then a surcharge of fill is added while charges of dynamite are placed as shown in Figs. 2 and 3. When these are fired, settlement is obtained as in Fig. 4, and the operation repeated per Fig. 5. Ditching dynamite is used, and the holes fired by propagation. The loads are placed from 3 to 6 ft. apart, and usually loaded with 1 lb. per foot of muck.

The advantages of this method are that shooting never holds up the contractor, that holes are easily and quickly made, that each blast not only drops the surcharge into place but compacts the fill already in place, and that settlement can be watched more closely and load varied to meet conditions as they arise.

AN IMPORTANT RAIN CYCLE OF 152 YEARS

By HALBERT P. GILLETTE

AN Australian civil engineer, T. W. Keele, was the first to call attention to a rain cycle of the order of the one hereinafter discussed. In the Proceedings of the Royal Society of New South Wales, in 1910, Keele published evidence of what he designated as "a grand cycle." Unfortunately his paper has not been known to many cycle researchers. Still more unfortunately, Keele assigned a length to the cycle that his own data do not support. He called it 171 years, but he arrived at that length by assuming that rain cycles are harmonic. Starting with the so-called 19-year cycle, which was first discovered in 1846 by Clark in Australia, Keele thought he saw evidence of a cycle of 3×19, or 57 years. Then he thought that his "grand cycle" must be exactly either 2 or 3 times 57, and finally decided in favor of 3×57, or 171 years. Although his data are not sufficient to establish the length of the cycle with much accuracy, they do show a cycle of the order of 150 years, as I analyze them.

Keele's data consisted mainly of the high water levels of the Nile from 1736 to 1908, and he used a very ingenious method of disclosing the "grand cycle." It is "the mass diagram" that American hydraulic engineers had developed for other purposes. Thirteen years later (1923), the then chief of our Weather Bureau, C. F. Marvin, re-invented the same method. Marvin evidently knew nothing of Keele's investigation. He called it "the accumulated sums of departures method," which describes it well. It consists in first calculating the mean annual rainfall, and then finding the plus or minus departure of each year's rainfall from that mean. The algebraic sum of these departures, from the beginning of the record up to each year is plotted, and forms a departure curve that discloses any long continued up or down trend in the rainfall. The peaks of such a curve are not the rainfall peaks, for the former occur at the transition points where excessive rainfall changes to subnormal rainfall. To find the date of a rainfall peak from such a curve of accumulated departures, find a point midway between a valley and a subsequent peak of the curve.

Both Marvin's departure curve of New England rainfall and Keele's departure curve of Nile flood levels agree in showing a rainfall peak about 1870; and they both agree in showing a cycle of the order of 150 years. Keele's data begin in 1736 and Marvin's in 1750; so neither of them had much more than one cycle of about 150 years. It is evident that this precipitation cycle has noteworthy amplitude or it would not disclose itself so clearly in Keele's and Marvin's curves, when several shorter cycles tend to obscure this "grand cycle." Marvin did not assign any definite length to this cycle and did not even venture to call it a cycle, but the two highest peaks in his departure curve are of almost equal height and nearly 150 years apart. There is an intermediate but much lower peak, apparently due to a brief inversion of phase, or possibly to a short cycle.

Prior to Marvin's 1923 paper and subsequent to Keele's 1910 paper, Huntington, in 1914, published evidence of a cycle of 155 years in tree-rings. He used data from 1400 to 1900 A. D., and was therefore able to determine the length of the cycle with considerable accuracy.

I find this cycle beautifully disclosed in the Arizona pines rings measures by Douglass, covering the years 1385 to 1906. The amplitude of the curve is 20 per cent, and its last peak date was about 1868, as determined by the parallel column method. This is a greater amplitude than I have found for any other cycle in the Arizona pines.

The California sequoias are less susceptible than the Arizona pines to variations in rainfall, and when they become very old are not very satisfactory "rain gages." Using the Douglass measurements of the sequoias I was able to determine the length of Keele's "grand cycle" with considerable accuracy. It is 152.4 years. During the last few cycles in the sequoias the "grand cycle" seems to be of opposite phase to that in the Arizona pines, which is puzzling, because in the earlier years (back to 1300 B.C.) the phase is the same in the sequoias as it would be in the pines if they were as old, and the amplitude in the sequoias is 10 per cent.

Having such excellent evidence of an important precipitation cycle of 152 years, I decided to look for it in geological data, such as the thickness of annual clay laminae, or varves, in ancient glacial lakes. I found the "grand cycle" in the varves measured by Antevs in the Connecticut River Valley, where an unbroken series of 3,700 years has been measured; and I found it also in the varves of the Timiskiming Lake region in Canada where a series of 1,900 varves has been measured. I used the parallel column method of cycle analysis. Incidentally I found that "giant varves" were most common near the peaks of the 152-year cycle, from which the inference is clear that "giant varves" were not caused by the bursting of small glacial lake dames, but by very abnormal runoff due to the spring melting of heavy winter snowfall. Both De Geer and Anstevs have thought that "giant varves" were caused by the sudden drainage of lakes, due to bursting of dams, and have called them "drainage varves." They have failed to realize that springtime melting of new, flocculent snow is the primary cause of the year to year variation in the thickness of varves. The floods thus produced near the peaks of the 152-year cycle often have had great erosive power.

It is highly important to know that the varying thickness of varves is a function of precipitation rather than of variation in solar heat or in the length of summers; for we can now be sure that every rainfall cycle of 2 or more years' length can be found in the varves.

Since the 152-year cycle was capable of causing very thick varves, I inferred that it might cause recessional moraines and halts in the rate of retreat of the ice-front.

This inference was soon verified. In "The Recession of the Last Ice Sheet in New England" Antevs gives a chart of the rate of retreat of the ice-front in Finland as determined by Sauramo. Sauramo found four successive halts that indicate a cycle of about 167 years, but my own study of the entire chart leads to a cycle of retreat not greatly differing from 150 years. However, the results of such a chart analysis do not begin to compare in accuracy with the results of a parallel column analysis of clay varve thickness.

In the above mentioned book by Antevs there is a map showing rates of retreat of the ice-front as determined by the surface contact positions of "bottom varves." The map also shows some of the 14 recessional moraines that Taylor found in the Berkshires in 1903. Taylor's moraines Nos. 9 and 11 average 10 miles apart; hence the distance apart of successive moraines in that region is about 5 miles. Fortunately, near these 2 moraines are accurately determined rates of recession of the ice-front, and they show about 30 years to the mile of retreat. This means that Taylor's moraines in that region were spaced about 150 years in time because they averaged 5 miles apart, center to center. The spacing of the 14 moraines averages 3.5 miles, being closer than that to the south and farther than that to the north, as we might expect.

Taylor found several parallel ridges on many of these moraines, but their spacing is not given with sufficient accuracy to determine the length of the causative cycles. The cycle is of the order of 20 years, and may be either the 18.85 or the 23.8-year cycle. I find evidence of a similar short cycle in Maine's glacial eskers, where they are not continuous.

W. C. Alden (U. S. Survey Bull. 760, 1925, p. 13-105) has written a remarkably informative monograph on the physical features of Massachusetts, in which moraines and drumlins ("horsebacks") are shown in great detail. A large scale pocket map (Plate VII) shows 12 successive lines where the ice-front halted in its northern retreat. The mean distance apart of these lines is about 3.3 miles. This is very nearly the mean spacing of the 14 moraines in the Berkshires, as determined by Taylor. The drumlins appear, at first glance, to be spaced irregularly, but there are many places where the center to center spacing of a series of drumlins is almost equal, and is about one-sixth that of the spacing of the lines of halt in the retreat of the ice-front. Since, as above shown, such halts in the Berkshires were due to the 152-year cycle, it follows that the center spacing of many drumlins was due to the 23.8-year cycle. In the table given later it will be seen that the amplitude of the 23.8-year cycle exceeds that of every other short cycle. Hence it is not surprising that it often caused an increase in the deposition of glacial gravel, sand, etc., in the form of drumlins and kames, at regular intervals. The maps in this monograph show glacial "horsebacks" more strikingly than any other maps that I have seen.

The next evidence of the 152-year cycle was sought in ancient beaches on the shores of glacial lakes. On the glacial Lake Agassiz, which occupied the basin of the Great Lakes, Taylor found 12 beaches about 28 ft. apart vertically, and wonderfully uniform in their spacing. By using known rates of retreat of the ice-front I was able to approximate the life of this ancient lake and by dividing that life by the number of beaches, I arrived at a cycle of the order of 150 years. Taylor speaks of there being 6 "strands" on one of the beaches, and his chart indicates a similar number on some other beaches. This indicates a short cycle superimposed upon the 152-year cycle.

It is evident that as the ice-front retreated, precipitation was decreasing and glacial lake levels were falling. But the precipitation peaks of the 152-year cycle caused a sufficient halt in the decline of lake levels to permit waves to build beaches, like the 12 above mentioned.

Let us now sum up the evidence as to a cycle of the order of 152 years:

1. Keele's discovery of a "grand cycle" in the floods of the Nile.
2. Huntington's discovery of a cycle of 155 years in tree rings, from 1400 to 1900 A. D.
3. Marvin's discovery of "a secular cycle" in the rainfall of New England.
4. Sauramo's discovery of a cycle of the order of 167 years in the rate of retreat of the ice-front in Finland.
5. My finding of a cycle of 152 years in the sequoias back to 1300 B. C.
6. My finding of a similar cycle in the clay varves of New England and of Canada.
7. My finding of a similar cycle in the time spacing of recessional moraines in the Berkshires, also in the Timiskiming Lake region.
8. My finding of a similar cycle in the time spacing of ancient beaches on glacial Lake Algonquin. Ancient lakes Agassiz and Lahontin show the same cycle of old beaches or terraces.

The last peak of the 152-year cycle was about 1868. Hence its next valley will be about 1944. Since this cycle is capable of causing dry periods 30 or more years long, it is probably the main cause of recent dry years. However, since there are several short cycles of considerable amplitude, not every year is dry near a valley of the 152-year cycle.

There is no planet whose orbital period throws any light on the cause of this cycle. Nor is there any evidence in the curves of sunspots that their frequency is responsible for it. No plausible causation theory of any sort has suggested itself to me other than the electron-shell theory. An electron-shell whose axis gyrates in 152 years could cause a precipitation cycle of that length. The electro-shell may be terrestrial, solar, or planetary. Certain facts indicate that it is a terrestrial electron-shell.

There is one important advantage in studying long cycles, namely, their fewness. So many short cycles exist that they obscure one another; whereas the long cycles stand out boldly. There is a very long cycle of about 1,400 years and a much longer one of 26,000 years that will be discussed in future articles. The geological evidence of their existence is expressive. The longer cycle is so clearly associated with the gyration of the earth's axis as to throw light on the nature of the cause of all cycles.

In addition to the 5 cycles above mentioned there are 3 others whose amplitudes exceed 10 per cent, as determined from the thickness of the annual rings of the Arizona pine measurements of Douglass subsequent to A. D. 1385. With the exception of the 2.03 year cycle in calculating whose amplitude I used only the year 1860 to 1891, the amplitudes of the cycles were deduced from Arizona tree-rings covering more than 500 years. It is interesting to note that the amplitude of the 2.03-year rain cycle at San Diego, California, was 15 per cent for the period 1860 to 1891, or 50 per cent greater than shown by the rings of the pines. The San Diego rainfall relates to the "seasonal years" ending June 30.

The amplitude is the percentage by which a maximum ordinate of the given cycle curve exceeds the mean; the cycle curve in all cases being deduced by the parallel column method.

The accompanying table gives data as to 8 cycles that have large amplitudes. It is, I believe, the first published attempt to show the relative amplitudes of precipitation cycles. Douglass has so clearly correlated rainfall with the thickness of pixe rings in Arizona that the amplitudes given in this table may be safely taken as indicating the approximate amplitudes of precipitation in regions having a relatively short season of rainfall.

The foot-note to the table gives some information about each of the 8 cycles.

EIGHT IMPORTANT PRECIPITATION CYCLES

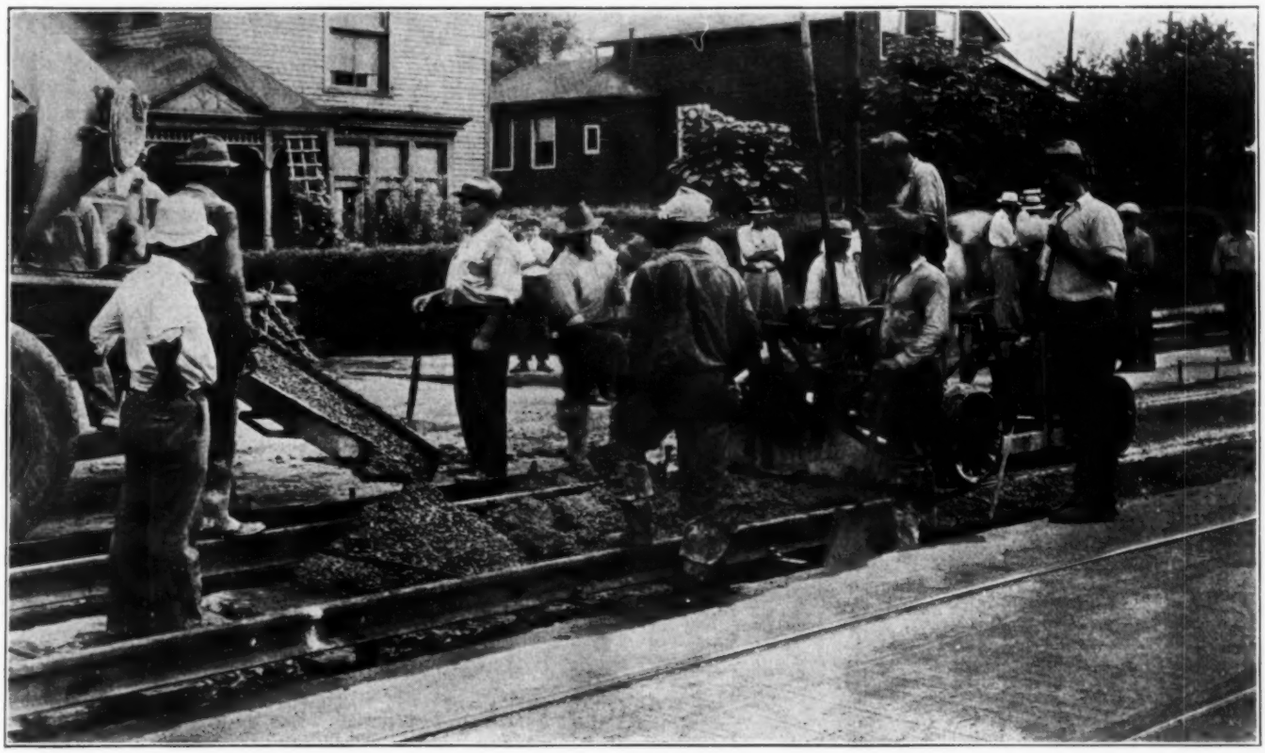
Cycle, Year	Amplitude, Per Cent	Precipitation Peak, A. D.
2.03	10	1874
5.67	15	1924
13.93	12	1927
18.85	11	1928
23.80	16	1929
152.4	20	1868
1,400	..	1320
26,000	..	16,300 B.C.

Foot Note: The cycle of 13.93 years has usually been regarded as being exactly 14 years. The cycle of 18.85 years is commonly said to be exactly 19 years. The cycle of 23.8 years has been assigned values ranging from 22 (= double Schwabe's sun spot cycle) to 25 years. The 2.03-year cycle was first announced by Hill and Archibald of India, in 1877, and called a 2-year cycle, resulting from "the compensatory law." It was discovered in America by Clayton in 1885, and also called by him 2-year cycle. In 1919, Douglass announced it in the Arizona pines; and De Geer, in 1926, announced it in the clay varves of Sweden. Of all the cycles it is the most apparent, especially in regions having a short rainy season. The 5.67-year cycle is commonly regarded as being exactly half of the Schaube sun spot cycle, whose length averages about 11.2 years. However, it has no relation to that cycle, as appears when its early peaks are compared with those of the Schwabe sunspot cycle. The 1400-year cycle was discovered by Clough in 1933. The 26,000-year cycle was found to be of that length and the date of its last peak determined by Gillette. It had previously been regarded by Blyth, Gilbert and Bradley as being a cycle of 21,000 years; but none of them had determined its peak date, for they used undated geological strata. Of cycles between 2 and 26,000 years, I have yet to find any but these 8 with as great an amplitude as 10 per cent. While the Arizona pines can not be used to find the amplitudes of the two longest cycles, the geological effects of those two cycles are such as to indicate amplitudes fully as great as that of the 152-year cycle. Huntington's curve of sequoia ring thicknesses indicates an amplitude of 10 per cent for the 1400-year cycle; and it would doubtless be much greater in the Arizona pines for the short cycles often have twice as great amplitude percentage in the pines as in the sequoias.

▼

BRICK PAVEMENT SPECIFICATIONS.—The recommended standard specifications for vitrified brick pavement and brick parking strips and gutters, adopted by the Brick Pavement Committee of the American Society of Municipal Engineers, have been put in printed form by National Paving Brick Association, National Press Bldg., Washington, D. C. Copies can be obtained by addressing the association.

Heavy Earth Moving Equipment on Route 90 at Sparkland, Ill. J. L. Wells Co., Rock Island, Ill., Contractor



Great Care Was Used for Accurate Water Control. Complete Penetration the Full Width of the Rail Base Was Obtained With 15 to 30 Seconds of Pulsation

VIBRATION AND POWER SCREED USED ON STREET RAILWAY PAVING

BEFORE starting its 1934 paving program, the Cleveland Railway Co., Cleveland, O., made thorough studies to improve quality of concrete and to obtain maximum economy from its use.

After these studies, changes and improvements were made in past practices. The result is an extremely high quality roadway at reasonable cost.

Of particular interest was the use of vibration. A number of sections had been placed with a pulsator and a new type of high speed vibrating screed. Thorough investigation was made of these sections.

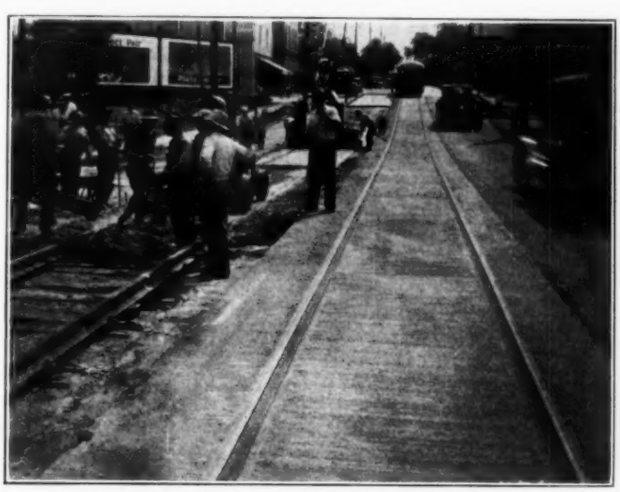
In general, the roadways inspected were in good condition. Some scaling of the surface was found on the Washington Park Bridge and on east 55th St. East 105th St. presented a variable surface, from excellent to a scaling. Wearing is evident at flanges and at joints.

New Practices Adopted.—For the new work it was determined that:

1. Mixes should be modified to eliminate harshness.
2. Water control should be carefully regulated; and
3. Condition of surface during finishing should be carefully observed and the finishing adjusted to prevent overworking.

After a thorough study of trial batches, a mix (dry basis) of 672 lb. cement, 1,375 lb. sand, and 2,075 lb. limestone (nominal ¾ in. size) was used, with 5½ gal. of water per sack of cement. This batch produced 1.11 cu. ft. of mixed concrete.

This mix was quite sensitive to water, an addition of 0.1 gal. per sack of cement affecting the workability noticeably.



Note the Short Space in Which the Entire Operation Is Confined; Also Excellence of Finished Car Track at Right

The Self-Propelled Power Screed Finished the Surface and Cut the Flangeways

The work done in 1934 consisted chiefly of reconstruction. Street surface was removed to the old concrete base. To old steel ties, 100 lb. tee rails were fastened with steel clips and bolts through metal shims. Where necessary, old ties were replaced. Tie plates were welded to the ties. Space between the rail base and the concrete base varied from ½ to 1½ in. Round tie rods, approximately 4 ft. on centers, were spaced between ties.

Placing Concrete.—After the concrete base was thoroughly cleaned and roughened, it was wetted thoroughly just prior to depositing the new concrete.

Ready mixed concrete was supplied by the Metropolitan Concrete Corp. Concrete was delivered to the job in Paris Truck mixers, hauling 3.9 cu. yds., or 3½ batches, per load. The concrete was dumped direct from truck to the center of the roadway.

Concrete Vibrated in Place with Pulsators.—A pulsator was then clamped to the rails midway between tie plates and operated until the concrete has settled well along the rails and had flowed under the rail bases. The space between the concrete base and the rail was as little as ½ in. The effect of the pulsator in causing mortar to flow the full width of the rail base and completely fill this space was remarkable. Care was taken to stop vibration when embedment was noticeably complete. Where space was not too narrow, 15 to 30 seconds was usually sufficient. Either a head of concrete or pressure on the top caused the bottom of the concrete to respond more readily to the pulsator.

Shovelers, working in front of the pulsator, distributed the concrete over the area to be filled, to be sure no unfilled spaces remained. Pulsators were positioned every 4 ft. Two International pulsators of the standard type were kept on the job, one being a standby unit.

Strict attention was paid to water content. If the mix was too dry, it did not transmit impulses properly, while in wet mixes the mortar was too fluid to hold the mix together.

Track-Mounted Power Screed.—As soon as pulsation was completed, a track-mounted power screed leveled the surface off. This self-propelled screed was made in the company shops, using the motor of an old Koehring mixer and parts of an old Lakewood finishing screed. It was built so a shoveler could ride on each end of the screed, whose duty it was to keep plenty of concrete in front of the screed. This "Roll" of concrete ahead of the screed was found to be important in obtaining a proper surface.

The screed travels at speeds up to 7½ ft. per minute. It has a transverse sawing motion, with stroke adjustable to 3½, 5½ or 7½ in. as desired. The 3½ in. stroke seemed most satisfactory. The screed is heavy, consisting of heavy plank shod with a metal base, having flaring ends outside the rails. Both in front and behind the screed are novel but effective flangeway formers, heavy metal drags which form the groove along the inside of the rails.

The screed was passed forward, backward, then forward again. Wooden flangeway strips were then placed in these grooves after which a heavy, two-man screed was worked back and forth along the head of the rails with a diagonal sawing motion, which compacted the surface and brought any excess water to the surface and worked it to the sides. Flangeway strips were then removed and the surface wire-broomed, removing any further laitance scum and water, and giving a slightly roughened surfaced. The surface was then covered with 2 layers of burlap as soon as possible and kept wet by sprinkling for a minimum of 3 days, and wet down a minimum of 7 days.

Old Roadway Cleared to Concrete Base, and Rails Secured in Position. In Some Places Clearance Between Concrete and Rail Base Was Only ½-In.

Shovelers Distributed the Concrete, Giving a "Head" on the Desired Thickness of the Finished Surface, Before Pulsation

STREET MAINTENANCE IN A CHICAGO SUBURB

IN the year 1917 an extensive program of street repairs was undertaken in Winnetka, Illinois, a village of 13,000 population, located 20 miles from Chicago. The work, for the most part was of an obviously necessary character, and the program was designed for immediate needs rather than as a basis for a permanent maintenance policy. Nevertheless there gradually developed from it a system of continuous maintenance which village authorities believe best meets the needs of their community. An important principle—perhaps the cardinal principle—of this policy is that within a strictly residential community, such as Winnetka, it is better to provide a maximum mileage of good, usable pavement at all times than to make comparatively large expenditures on the improvement and maintenance of a few important streets. Maintenance costs in Winnetka compare favorably with surrounding communities, and its streets are recognized as being in a generally superior condition.

Paving History.—The Winnetka paving record dates from 1895 and 1896, during which two years a total of 7½ miles of waterbound macadam was laid. More of the waterbound type was added until the year 1909, when it totalled slightly more than 10 miles. None was built thereafter.

A block or two of bituminous macadam was laid in 1900; sheet asphalt was begun on a small scale in 1905; and the first brick was a ⅜ mile stretch laid in 1907. A stub end of concrete was built in 1911, and a ¼ mile length added in 1915.

Pavement mileage was increased steadily, but there was no important change in type until the year 1916, when 8 miles of the old waterbound macadam was scarified, evened up, and given a tar surface. The remaining sections of waterbound macadam were similarly treated during the next two years. By the end of 1918 the pavement record shows the following:

	Miles
Concrete, Brick and Asphalt	17.6
Tar and Bituminous Macadam	11.7
Cinder and Earth Roads	11.8
Total	41.1

It may be noted that in addition to this 41.1 miles, there was a small mileage of "private roads"—roads constructed and maintained at private cost, though generally open to public use—and a total of about 2¼ miles of road along the village boundaries, maintained either by the county or the township. There are only a few alleys in the village.

The present mileage, exclusive of alleys, private roads and roads maintained by county or township, is:

	Miles
Concrete, Brick and Asphalt	28.9
Tar and Bituminous Macadam	11.9
Cinder and Earth Roads	2.3
Total	43.1

A few of the road surfaces are only 18 ft. wide; the majority are from 20 to 25 ft.; the Center street-Linden street improvement is 40 ft.; and there is one block of 54 ft. pavement.

The lengths and areas given in this article are net, having been computed without duplication of street intersections.

Maintenance Costs.—Beginning with the fiscal year 1918-19 (the year ending March 31, 1919), maintenance costs are divided into two groups—concrete, brick and asphalt in the one—all classes of macadam in the other. Maintenance of cinder and earth roads is included with the cost of macadam prior to the fiscal year 1923-24, so that unit maintenance costs of macadam as given in the table from 1918 to 1923 are somewhat too high, the errors being of the general order of 10 per cent.

Another factor tending toward an appearance of unduly high maintenance is due to the system of cost keeping and accounting. Under this system all work, short of complete replacement of pavement, is charged to maintenance though some of it might properly be treated as replacement and a considerable amount constitutes actual betterment.

Costs given in the tables do not include sidewalk, parking, sewer, or catch basin maintenance. Street cleaning costs also are kept separately from maintenance expense.

Special Maintenance Features.—Inevitably there is a wide variation in costs from year to year, even under a system of "continuous maintenance," probably the chief cause being the varying ages of large blocks of pavement.

After the resurfacing of original waterbound macadam streets with tar or asphalt, a general resealing of the surface was made from time to time as seemed necessary. Now, however, a full seal coat is applied regularly once in 3 or 4 years.

Cracks in brick or concrete are filled, raveling holes in asphalt or macadam are repaired, and other small defects are remedied as soon after their appearance as weather permits. This prompt attention to minor repairs, in conjunction with the application of a full seal coat at regular intervals, maintains the pavement in continuously good condition.

The raising of sunken slabs by the mud-jacking method has also been an occasional repair item.

Work in 1929-30.—The relatively high maintenance costs of the concrete, brick, asphalt group for the fiscal year 1929-30 were due to the taking up of some 60,000 sq. yd. of asphalt surface, evening up the base, laying a new top of 2½ in. penetration macadam, and applying a seal coat. The old work so repaired was chiefly a 2 in. "Westrumite" top laid on 4 in. of concrete in 1909. The repair work was done under a special assessment, levied in a single installment, one-fourth the cost being charged to the abutting property, and three-fourths being paid from the village vehicle tax.

Some annoyance from bleeding has been experienced on pavements reconstructed in this manner, and it is planned that on future work, of which there will be considerable, the repaired and evened concrete base will be covered with 1½ in. of pre-mixed coarse aggregate, on top of which will be laid a ½ in. Tarvia-lithic wear-

ing surface. A block repaired in this manner in 1932 at a cost of $1.08 per square yard has given excellent satisfaction.

An unusual amount of resurfacing of macadam streets in this same fiscal year also resulted in higher than average costs.

Macadam Treatments.—Resealing of macadam streets, as now conducted, consists in the application of ¼ to ⅓ gal. Tarvia "A" and from 30 to 35 lb. of washed roofing gravel per square yard. The gravel is distributed by truck, the tail gate being slightly opened, and the truck backed over the freshly tarred surface. This method is found to be cheaper and to give more uniform results than the old method of spreading by shovel from stock piles at the roadside.

The graveled surface is rolled, and later the loose gravel which has been scattered by traffic is broomed from the sides to the center by the power street sweeper. This process may be repeated 2 or 3 times before the maximum amount of gravel is consolidated under traffic. Any surplus remaining thereafter is swept up and spread on earth or cinder streets.

As previously stated, this treatment is given once every 3 or 4 years. In 1934 it was applied to about 150,000 sq. yd., at a unit cost of approximately 8 ct. for all items of labor and material. Truck drivers, roller and sweeper operators are paid 70 ct. per hour—laborers 50 ct. Gravel is purchased in carload lots at $1.67½ per cu. yd. f.o.b. Winnetka. Tarvia costs 12¼ ct. per gallon delivered hot on the street.

Street Cleaning.—Street cleaning costs for the past 10 years are given in the table following. The refuse is swept up by an Elgin sweeper, dumped at suitable points, and carried away by truck. Aside from truck loading there is little hand labor. In the business sections, streets usually are swept twice a week—in residential districts at longer intervals. In the fall the sweeper is constantly busy collecting leaves.

STREET CLEANING COSTS (NOT INCLUDING SNOW REMOVAL) OF CONCRETE, BRICK, ASPHALT AND MACADAM PAVEMENTS
(Fiscal Year Ending March 31)

Year	Total Cost	Length, Miles	Cost per Mile
1925-26	$ 4,203	38.2	$110
1926-27	4,939	39.3	126
1927-28	4,936	39.9	124
1928-29	4,669	40.6	115
1929-30	3,771	40.6	93
1930-31	4,231	40.6	104
1931-32	5,614	40.6	138
1932-33	4,027	40.8	99
1933-34	2.864	40.8	70
1934-35	3,250*	40.8	80*
Total and average	$42,504	402.2	$106

*Budget appropriation.

In recent years a record has been kept of cost per gutter-mile swept, the mileage being taken from the sweeper speedometer. These costs have been as follows:

1929-1930	$2.22
1930-1931	2.01
1931-1932	1.74
1932-1933	1.64
1933-1934	0.98

They include the entire cost of operating the sweeper and removing the debris, but no interest or depreciation charges. The sharp reduction in cost in the year 1933-1934 was due chiefly to the use of a new sweeper, displacing an old and nearly wornout machine.

State, County, and Township Maintenance.—The legal status of some of Winnetka's streets is interesting in its relation to maintenance. Sheridan Road, the oldest, and in some respects the most important north and south highway through the village, is a state bond issue route, and as such is maintained at state expense for a width

MAINTENANCE COSTS OF CONCRETE, BRICK AND ASPHALT PAVEMENTS
(Fiscal Year Ending March 31)

Year	Total Cost	Length, Miles	Area Sq. Yd.	Cost per Mile	Cost per 100 Sq. Yd.
1918-19	$ 1,019	17.6	241,630	$ 58	$0.42
1919-20	383	22.8	309,940	17	0.12
1920-21	279	23.0	311,680	12	0.09
1921-22	643	23.5	317,760	27	0.20
1922-23	2,193	23.5	317,760	93	0.69
1923-24	3,804	24.8	331,580	153	1.15
1924-25	1,916	26.3	352,650	73	0.54
1925-26	6,573	26.3	357,690	250	1.84
1926-27	11,218	27.2	377,690	412	2.97
1927-28	10,081	27.8	384,530	363	2.62
1928-29	16,486	28.5	389,940	579	4.23
1929-30	25,884	28.5	390,470	908	6.63
1930-31	8,859	28.7	393,130	309	2.26
1931-32	4,305	28.7	401,510	150	1.07
1932-33	3,864	28.9	408,660	134	0.95
1933-34	3,953	28.9	408,660	137	0.97
1934-35	5,450*	28.9	408,660	189*	1.33*
Total and average	$106,910	443.9	6,103,940	$241	$1.75

*Budget appropriation.

MAINTENANCE COSTS OF TAR AND BITUMINOUS MACADAM PAVEMENTS
(Fiscal Year Ending March 31)

Year	Total Cost	Length, Miles	Area Sq. Yd.	Cost per Mile	Cost per 100 Sq. Yd.
1919-20	$ 8,652†	11.7	168,450	$740†	$5.14†
1920-21	8,851†	11.7	168,450	757†	5.26†
1921-22	7,299†	11.7	168,450	624†	4.33†
1922-23	8,829†	11.8	169,320	748†	5.21†
1923-24	14,449	11.9	170,880	1,213	8.46
1924-25	9,626	11.9	169,770	809	5.67
1925-26	4,848	11.9	169,770	408	2.86
1926-27	12,068	12.1	173,330	998	6.97
1927-28	5,878	12.1	173,330	485	3.39
1928-29	5,503	12.1	173,330	455	3.17
1929-30	12,768	12.1	173,330	1,055	7.37
1930-31	4,103	11.9	171,150	345	2.40
1931-32	2,229	11.9	171,150	187	1.30
1932-33	2,417	11.9	171,150	203	1.41
1933-34	2,211	11.9	171,150	186	1.29
1934-35	13,340*	11.9	171,150	1,121*	7.79*
Total and average	$123,071	190.5	2,734,160	$646	$4.50

†These costs include the maintenance of cinder and earth road surfaces. They are approximately 10 per cent higher than the costs for macadam alone.
*Budget appropriation.

MAINTENANCE COSTS OF EARTH AND CINDER ROADS
(Fiscal Year Ending March 31)

Year	Total Cost	Length, Miles	Area Sq. Yd.	Cost per Mile	Cost per 100 Sq. Yd.
1923-24	$ 275	4.9	56,020	$56	$0.49
1924-25	317	3.4	38,920	93	0.81
1925-26	135	3.4	38,360	40	0.35
1926-27	62	3.0	32,960	21	0.19
1927-28	44	2.8	29,650	16	0.15
1928-29	54	2.5	27,090	22	0.20
1929-30	84	2.5	27,090	34	0.31
1930-31	154	2.5	27,090	62	0.57
1931-32	558	2.5	27,090	223	2.06
1932-33	230	2.3	24,620	100	0.90
1933-34	160	2.3	24,620	70	0.62
1934-35	250*	2.3	24,620	109*	1.01*
Total and average	$ 2,323	34.4	378,130	$68	$0.61

*Budget appropriation.

of 20 ft. The work is done by the village under contract, and is billed to the state. Its cost is included in the tables here given.

The Center street-Linden street route, the other important north and south highway, is a state aid route which ultimately, like Sheridan Road, will be state-maintained for a width of 20 ft. As it is new, there has been very little expended on it to date. Traffic lines are painted, and cracks and joints filled by state forces.

Hibbard Road, a 1½ mile north and south route located largely at the village limit, is a county highway, maintained entirely at county expense, and is not included in the tables here given. An 8/10 mile portion of Hill Road, running along the southern boundary of the village is maintained entirely by the township highway department, and is also excluded from the tables.

An account of snow removal methods and costs in Winnetka was given in the September 1934 issue of ROADS AND STREETS.

Management.—All streets and municipally-owned utilities in Winnetka are under the direction of Herbert L. Woolhiser, Village Manager, incumbent since 1917. The manager system as applied in this community has proved highly satisfactory to residents and property owners.

▼

Reflooring Approach of Eads Bridge, St. Louis

An interesting reflooring job was carried out last fall on the historic Eads Bridge at St. Louis, Mo. The new floor was installed on the south half of the east approach.

The work involved the installation of 3 in. thick Carnegie Steel Co. I-Beam Lok floor on a roadway about 22 ft. wide and 1040 ft. long on a grade of 4 per cent with a street car track on it. It was laid on a steel viaduct built in 1894-96 consisting of an 120 ft. truss span and plate girder spans from 32 to 40 ft. in length. The new floor replaced a wood floor consisting of nailing strips on I-beam stringers, decking and wood blocks, the street car rail being laid directly on the decking. Except to the extent necessary to provide stringer support for the new street car rail, there was no change in the location of the I-beam stringers, although a few which had deteriorated were replaced. The I-Beam Lok floor is about 9 ins. lower than the old floor, which made a raise and adjustment of the new floor necessary at each end to fit it to the existent structures. This was accomplished at one end by raising the girder spans and at the other by steel blocking on the floor beams under the stringers.

Placing the Ready Mixed Concrete

Concreting Completed Between the Rails and Between the Rails and Curbing

There is a concrete curb 8 ins. high, with angle iron cast into it to take the curb wear on each side of the roadway. The street car rail is set on a C-beam and securely welded to it, there being an I-beam immediately adjacent on each side thereof forming a trough which was filled with concrete. Because of the street car track, particularly the curved portion, it was necessary to have the I-Beam Lok, which comes in slabs 4 ft. wide, cut to exact dimensions and fitted to each location.

All concrete was delivered ready mixed on the job. All of the steel was welded together wherever possible.

The work was done for the Terminal Railroad Association of St. Louis, of which H. J. Pfeifer is chief engineer.

▼

Pavement Striping with Bituminous Materials

The Maintenance Department of the Indiana State Highway Department has experimented with white and yellow traffic paint and also bituminous material in efforts to increase the effectiveness of center and multiple traffic lane marks for night driving. According to a paper by C. W. McClain, Engineer of Maintenance at the recent Purdue Road School, the paint lines are effective for the driver under his own light but fade out under the light of approaching cars just when he needs the added protection most. Mr. McClain stated that to eliminate this objection they had gone to cut-back asphalt with about 1½ lb. of powdered asphalt to the gallon added. This does two very desirable things: it leaves a very glossy surface which shines under light and, because of the quick drying effect of the asphalt powder, eliminates the use of sand covering. This work is best done when air temperatures are not over 35° F. Some criticism is made because the line is slippery when wet, but the small width involved minimizes danger of prolonged skidding. The slight skidding involved only tends to encourage traffic to cross the line only when necessary.

Another effective method, especially on black pavement, is the cut-back asphalt line followed immediately with fine white limestone screening. This makes a very lasting line and depends on its white color and some appreciable thickness for its effectiveness.

▼

CITY MANAGER PLAN FOR TWO LARGE CITIES.—The City Manager form of government will become effective in Schenectady, N. Y., in January, 1936. Toledo, O., also has adopted the plan, which becomes effective in January, 1936.

EDITORIALS

The Profit Motive

COMPETITION is often wasteful, but the lack of it is usually more so. The wastefulness of monopoly is perhaps best seen where governments exclusively exercise certain functions without appreciable assistance from competing individuals or firms. Take our weather bureau for example. It has been in existence for sixty years. Its main aim has been to forecast weather for the guidance of farmers. It is a part of the Department of Agriculture. For many years its annual expenditures have approximated $4,000,000. Yet what is there to show for all this outlay? Only weather forecasts of about two days in advance. That sort of forecasting is almost useless to the average farmer. Hence the main aim of the weather bureau remains as remote of attainment as it was three generations ago. Every large civilized government has a weather bureau, and all have failed in their main objective.

It may be replied that weather problems are so difficult that centuries will elapse before the most important of them will be solved. But note well this fact: Our weather bureau has never had more than two or three men engaged exclusively in analyzing weather data with the object of finding weather cycles. Judging by the small number of articles on the subject, the same is true of other weather bureaus. Since long-range accurate weather forecasting will always be impossible until all important weather cycles shall have been discovered, it follows that every weather bureau has been wasteful in its expenditure of public funds. Sir John Herschel, nearly a century ago, criticized the amassing of weather data without any serious attempt at ascertaining the underlying significance of the data. It is scarcely conceivable that were the profit motive involved, a private corporation would have been thus wasteful of the funds available for weather research.

Take another branch of government for another illustration of the wastefulness of monopoly, namely the military branch. If there has been a single outstanding military invention made by any army or navy organization or individual it is not recorded in Encyclopedia American under Inventions. From explosives to the guns that use them, from barbed wire to tanks, from steamships to their armament, the noteworthy inventions have all been made by men actuated by the profit motive.

There are two functions that every government exercises and has exercised from the beginning of government, namely protection of life by means of its military power, and protection of property by its judicial bodies. Never has there been a great war that did not disclose unpreparedness. The delays and expense of litigation have been the subject of innumerable articles in economic literature and the basis of countless stories and novels in all tongues. So costly is litigation that the motto of many a business man is to compromise out of court whatever the cost.

It has recently become popular in America to decry the profit motive. Yet where that motive is absent, just cause for criticism is usually most apparent. The profit motive with its attendant competition is not without its wasteful features. What industrial activity is? The real question should be whether the profit of progress is greater than its cost in a monopolistic or in a competitive society. Let the question be just put, and let the facts answer. It is not necessary to seek the answer only by comparing socialistic with individualistic forms of government. As above indicated the answer can be found by comparing bureaus where the profit motive is absent with individual and corporate activities where it is present.

A Winter's Lesson

THE famous comment that much has been said about the weather but little done about it, leaves out of account man's conquest of weather's effects. This conquest is broad, and in large part obvious: it has grown with civilization, and is growing faster now than ever.

On streets and highways it takes various forms, uppermost in our minds at the close of winter being the clearing away of snow. In some places this has been done well—in others poorly or not at all. Probably in very few has it been carried to the point of maximum public economy—a point obviously difficult to determine. Let us glance briefly at the situation and its problems.

The winter now ending has been a snowy one in Chicago: that is, while not meriting the epithet "severe," it has given us several fairly heavy falls and a practically continuous cover since December. What has been its effect on motor travel and transport? Unfortunately this can be answered only in terms of individual opinions, based usually on limited observation and often on poor reasoning.

Certain facts, however, are fairly clear, the first being that motor traffic has been greatly reduced, and that the reduction represents a loss which will be made up only in minute part. Anyone, at almost any place, could observe this traffic diminution. In "The Loop" and the major arteries it was least in amount and shortest in duration because clearing operations were there pressed most vigorously and traffic itself helped much to clear the pavement. But in many normally busy suburban thoroughfares traffic practically disappeared at times, continued for days at a fraction of its usual volume, and remained conspicuously low as long as any considerable amount of snow lay on the road. When the highway was clear, its use returned to what might be termed a winter normal. Consider, in comparison, the preceding winter—the one of 1933-1934. That season brought a minimum of snow, and traffic hummed along as in early spring or late fall.

Traffic interruptions due to snow or any other cause strike widely. Shopping is interfered with, sales reduced, amusements curtailed; and any merchant will tell you that such losses are not made up. Car users are inconvenienced and lose both business and pleasure. These losses are difficult—perhaps impossible—to measure, but there is a special loss which can be determined as closely as need be. We refer to gasoline sales. Certainly a proper study of filling station operations should disclose within reason the loss in business due to uncleared snow. Perhaps the oil companies have already made such analyses, but if so we have not seen them. Publication of such information should be of distinct aid to municipal authorities in determining expenditures to be made for snow clearance.

The foregoing refers to losses through disuse of roads. Other losses occur *because* of their use—wear and tear, actual damage in some cases, lost time, low gasoline mileage.

It is our belief—a belief which we hope some day to support with data—that extensive increases in municipal snow clearance are justified by the savings they will bring.

Pleasant Street, Danbury, Connecticut, Tarvia-built in 1915. Twenty years have brought many changes to this pleasant New England community, but the Tarvia road remains as smooth, easy-riding and skid-safe as the year it was built.

Hundreds of Tarvia roads like Pleasant Street, Danbury, offer proof that Tarvia "can take it." Built in the days when thirty miles an hour was considered reckless speeding, these smooth, easy-riding, skid-safe roads now provide completely satisfactory pavement for the modern high-speed, quick-stopping and quick-starting automobiles of today. Cost records will demonstrate how soundly economical they have been to build and maintain. Let the Tarvia field man tell you about them. Phone, wire or write our nearest office.

Barrett Tarvia
GOOD ROADS AT LOW COST

THE BARRETT COMPANY New York Chicago Philadelphia Birmingham St. Louis Minneapolis Cleveland Boston Detroit Baltimore Youngstown Cincinnati Buffalo Rochester Syracuse Bethlehem Providence Toledo Hartford Portland, Me. Lebanon Columbus Milwaukee In Canada: THE BARRETT COMPANY, LTD. Montreal Toronto Winnipeg Vancouver

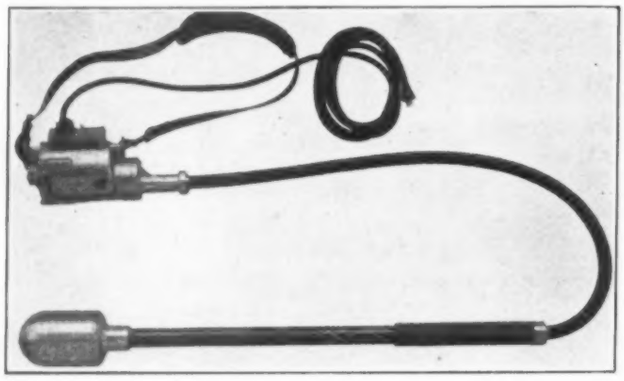
Yes—We would like you to mention ROADS AND STREETS.

NEW EQUIPMENT AND MATERIALS

New Concrete Vibrator

The latest addition to the line of "Berg" concrete surfacers of The Concrete Surfacing Machinery Co., 4667 Spring Grove Ave., Cincinnati, O., is the "Berg" concrete vibrator, Model "VA." The Model "VA" is a portable electric motor driven outfit, consisting of a light weight vibrator unit, attached to a flexible shaft driven by a motor unit. The motor unit is suspended by a shoulder strap with pad, from the operator's shoulder, leaving the hands free to operate the vibrator. Both vibrator and motor unit are ball bearing throughout. Standard equipment consists of a 5 ft. flexible shaft and casing. If desired, a 10 ft. shaft and casing can be furnished at additional cost.

The vibrator unit consists of moisture-proof rotor housing, enclosing an eccentric weight or rotor, which is mounted on a rotor shaft. A spindle extending through a tube is attached



"Berg" Portable Vibrator

to the rotor shaft and delivers power to the rotor. This tube serves as a handle for the vibrator.

The motor driven flexible shaft attached to this spindle causes the rotating assembly to rotate at high speed, thereby causing the housing to vibrate. This vibration is transmitted directly to the concrete, in which the housing is placed, producing waves of high frequency, which travel in all directions. This action assists the mixture in placing itself and reaching all parts of the construction work.

▲

Quick Adjustable Screeds for Crown Elimination

Because a great many state highway departments require the flattening of a pavement surface around curves, the Blaw-Knox Co., Pittsburgh, Pa., developed the quick adjustable screed for crown elimination illustrated herewith.

It can be installed on any Blaw-Knox finishing machine (either Ord or gas-electric type) and can be used for either concrete or bituminous road construction.

This adjustable screed eliminates a road building operation which usually required considerable time and held up the entire job.

The following is an example of this operation:

The pavement carried a 1½-in. crown. On entering a curve the first 75 ft. are used for transition from 1½-in. crown to flat, and the last 75 ft. coming out of the curve is transition from flat to 1½-in crown. This transition must, of course, be gradual.

Heretofore much effort was required to draw out or build up the crown in transition. This resulted in several hours' loss of paver time and consequent yardage.

The standard crowned screed also had to be flattened and recrowned or a flat screed had to be substituted, causing further mixer delay.

The Blaw-Knox quick adjustable screed is stated to eliminate a time loss on a paving job which ordinarily would hold up the job about three hours. Where numerous curves are encountered this time loss represents a considerable figure.

The quick adjustable screed remains in the finisher for both the crown and the flat section. By the use of cam levers and the operating spider, it can be gradually flattened or crowned while going through the paving transition without job delay.

The adjustment in crown is made while the finisher is in operation by simply turning the adjusting spider device. A gauge indicates the degree of change and the true crown at all times.

▼

"Freewheeling" Comes to the Drafting Room

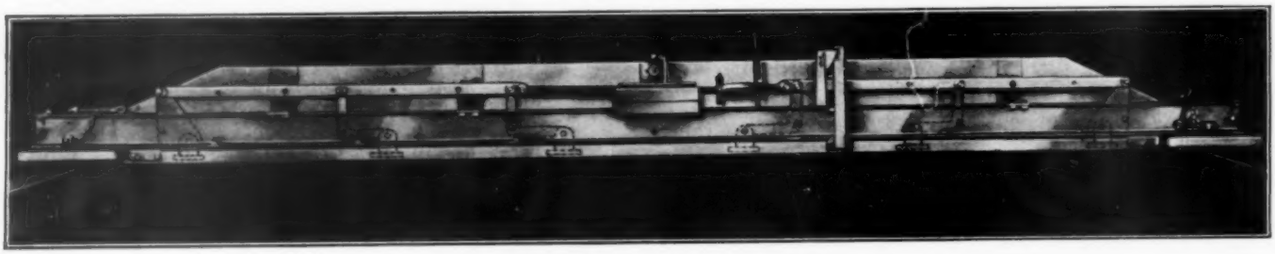
"Freewheeling" has come to the drafting room, with the introduction of a coaster drafting chair for engineering tables and a battery of coaster lights for illuminating drafting boards. Hamilton Manufacturing Co., Two Rivers, Wis., is the manufacturer.

The coaster drafting chair, in addition to providing an effortless lateral movement in front of a drafting table, permits a forward and backward movement through a pivot in the lower part of the frame. The seat may be adjusted for height and proper distance from the table, to fit individual needs. More

Coaster Drafting Chair

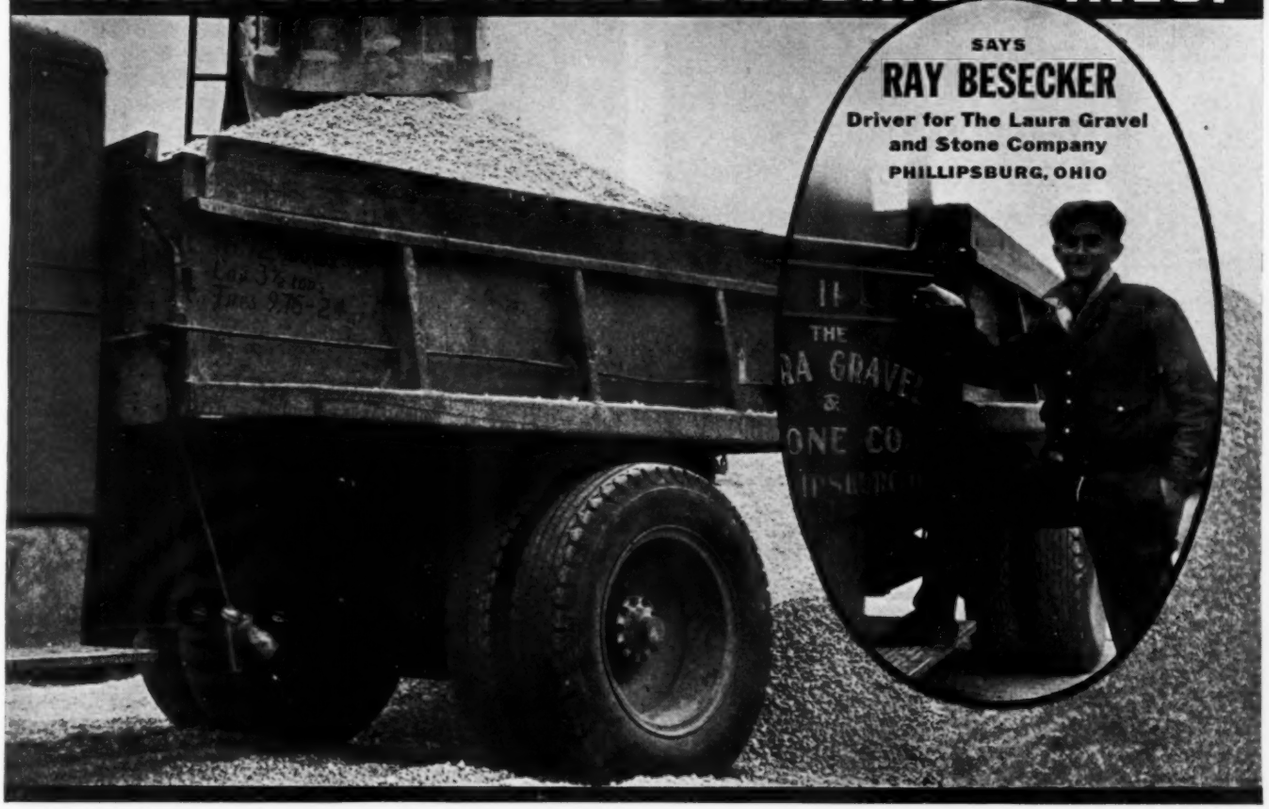
drawing tables may be used in a given area, it is said, because less distance is required between tables.

Front legs of the chair are supported on a lateral track attached to the drafting table, with ball-bearing fibre wheels running in a channel guide. The outside legs have ball-bearing casters which roll on the floor.



Blaw-Knox Quick Adjustable Screed.

"HAVE NEVER HAD A SIDEWALL FAILURE SINCE..USING THESE GOODRICH TIRES."



What does a truck driver think about tires? Well, listen to what Ray Besecker, driver for The Laura Gravel and Stone Company, says:

"For 15 years I've been driving trucks and I've never seen tires that stand up like these new Silvertowns. I haul eight-ton loads of stone over all kinds of roads and have never had a sidewall failure since we have been using these Goodrich Tires.

"I hate to make tire changes on the road—that's why I like Silvertowns."

There are no soft jobs at this plant—for men or for tires. Those big trucks bang their way over crushed rock, bounce over rough dirt roads and then hit it up on the highway. Just the sort of job where you would expect plenty of sidewall failures.

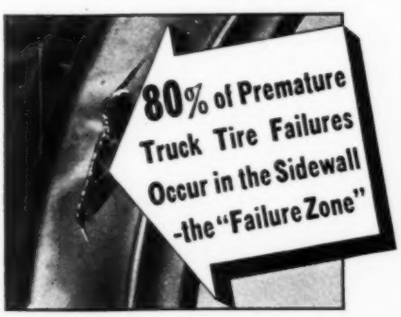
But not with Triple Protected Silvertowns! Every tire has a 3-way safeguard—designed to give positive protection against these money-eating failures. Look at this:

1 PLYFLEX—a *new*, tough, sturdy rubber material with greater resistance to stretch. A layer of Plyflex in the sidewall prevents ply separation—distributes stresses—checks local weakness.

2 PLY-LOCK—the new Goodrich way of *locking* the plies about the bead. Anchoring them in place. Positive protection against the short plies tearing loose above the bead.

3 100% FULL-FLOATING CORD—Each cord is surrounded by rubber. With ordinary cross-woven fabric, when the cords touch each other, they rub—get hot—break. In Silvertowns, there are no cross cords. No friction.

You pay no more to get Triple Protection—the invention that checks 80% of premature failures.



FREE! 44-PAGE HANDBOOK FOR TRUCK OPERATORS

Every truck owner, every driver should have this big 44-page data book. Gives commodity weights, load schedules, inflation schedule, dual spacings and other useful information. No obligation. Write for free copy. Department T-35, The B. F. Goodrich Company, Akron, Ohio.

Goodrich *Triple Protected* Silvertowns

SPECIFY THESE NEW SILVERTOWN TIRES FOR TRUCKS AND BUSES

SERVICISED

Servicised Cork Rubber Expansion Joint

EXPANSION JOINTS
CORK BOARD
METAL CUSHION JOINT
ASPHALT PLANK (Standard)
MINERAL SURFACED PLANK
CEMENT TREAD PLANK
WATERPROOFINGS
COURSE ROOFINGS

Servicised Sponge Rubber

Servicised Rock Surfaced Plank

Servicised Quality Products have been sold throughout the United States for upwards of 13 years. Thousands of installations attest the recognition and approval accorded them by State Highway Departments and Engineers.

Our products find ready acceptance and our distributors are given wholehearted cooperation in their sales efforts, for despite adverse economic conditions, there has been no let-down in the high standard of quality established when our first product was introduced.

Inquiries will receive prompt attention. Write today.

Servicised Felt Reinforced Joint

Servicised Type "B" Joint

SERVICISED PRODUCTS CORP.
6051 West 65th St.
Chicago, Ill.
Tel. Grove Hill 0423

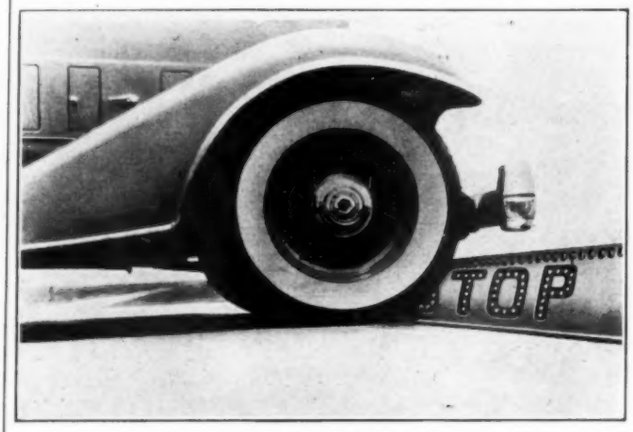
The chair seat and back rail are padded and covered with a durable brown leather-like material. The chair is of steel construction, finished in olive green enamel. All new Hamilton steel 4-post tables are equipped with bolts for attaching the new type chairs.

The new Hamilton-Calumet coaster drafting lights consist of three adjustable lights attached to a ball-bearing, rolling unit which runs in a channel at the back edge of a drawing board. This battery of lights may be moved along the back of the drawing board, wherever needed. In addition to the sidewise movement each individual lamp may be swung in a circle, thus giving the exact illumination needed in any particular area. The lights are never in the way and are instantly adjustable. The unit may be attached to any drawing table top. All parts are of steel, with the light arms of ½-in. brass tubing.

▼

Device for Eliminating Crossing Accidents

A device for the prevention of accidents at railroad crossings, placed in production recently by the Evans Products Co., Detroit, Mich., consists of triangular sections which form a horizontal barrier when raised above the pavement. The sections are constructed of reinforced steel with a concave surface, facing the approaching automobile; are studded with reflector buttons and have the word "Stop" lettered in reflector glass several times along the protector. At the approach of a train, an electrically operated mechanism in a sub-pavement chamber 75 ft. from the tracks, raises the protector 4 in. above the pavement when the train is 20 seconds from the crossing, allowing traffic to clear before reaching its full elevation of nearly 10 in. When not in use the Auto-Stop lies level with the pavement surface.



The Auto-Stop

Three advantages designed to make this protective device "foolproof" are:

1. Should a driver disregard the visual and audible warnings from the device itself, the automobile at a reasonable speed will be stopped forcibly by the barrier, without damage to the car. If the auto is traveling at a high speed the Auto-Stop will damage the car but will not injure the occupants. However, out of more than 750,000 cars observed at several Auto-Stop installations not one auto has collided with the device at its full height.
2. Lights and stop warnings at the pavement level are in the natural line of the driver's vision and can be seen for several hundred feet.
3. The Auto-Stop is especially designed to operate under all variations of weather conditions.

▼

New Indiana Truck

A new streamlined Indiana truck, priced at $695, is announced by The White Motor Co., Cleveland, O., builders of Indiana trucks and coaches. Volume delivery of the first of 10,000 units to be built this year will start March 15.

The new model, of 11,000 lb. gross capacity, marks Indiana's entry into the lowest price field. It will be merchandised by White branches and dealers. The new model is designed to fit every requirement of the light duty field.

Modern stream line appearance is a striking feature of the

chassis, achieved by the use of deep-skirted fenders, cadmium plated radiator grille and louvres and a sedan type cab. The new truck features a powerful 6-cylinder 263 cu. in. engine, hydraulic brakes and ventilated disc wheels.

Emergency Carbide Light Always Ready for Use

A new carbide emergency light weighing only 40 lb. when fully charged, and which burns for three hours, giving 8,000 candlepower, has recently been announced by the National Carbide Sales Corporation, Lincoln Bldg., New York City. Announced as a police emergency light, it has many other applications in the construction, municipal, aviation and railroad fields.

The reflector is mounted on a universal swing joint, so that the light may be shifted to any angle and may be easily folded down for carrying by a convenient handle above the carbide hopper. The unit is 3½ ft. high when extended for use, and 28 in. when folded.

Emergency Light

A 1¾ lb. charge of carbide placed in the hopper is sufficient for over three hours. The light may be operated intermittently, as needed, without the waste of any of the charge. By throwing a lever, the carbide is released a few grains at a time into the water tank below, and the rate of feed of the dry carbide is regulated automatically by the gas pressure. The light may be shut off by throwing the lever back to locked position. The tank is made of eighteen-gauge sheet steel, hot-dipped in lead after the tank is welded.

No spilling if the light is turned over. It will go right on operating when set upright.

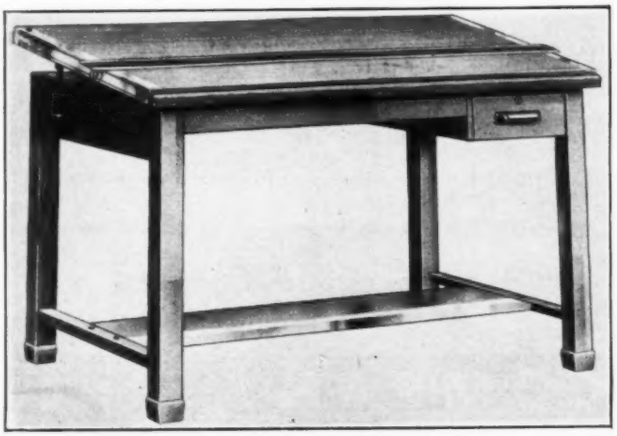
Steel and Wood Drafting Table Developed

A new line of "Steelwood" drafting tables has been introduced by the Hamilton Manufacturing Co., Two Rivers, Wis. As the name suggests, the tables offer a combination of the best practises in both steel and wood construction.

The cost of the steel-framed tables is stated to be no higher than four-post tables of all wood construction. Framework is of welded steel construction, insuring permanent rigidity, joints that can never become loose or wabbly, and freedom from annoying repairs. The drawer units are of wood construction, while the drawers themselves have steel fronts finished in olive-green to harmonize with the all-steel body.

The tables are being offered in three sizes, with a variety of drawer combinations to meet various drafting-room requirements. They are finished in olive-green baked enamel to match other steel equipment in drafting rooms or offices.

A new standard height has been incorporated in their construction. Instead of the standard 30-in. height, a new height



"Steelwood" Drafting Table

Specify

TRINIDASCO

—cold-laid Asphalt Pavements

Trinidasco—the Native Lake asphalt mixture that is laid cold—is prepared with the same grades of stone, sand and other mineral aggregate and Trinidad Lake Asphalt used since 1876 in the construction of standard types of Trinidad hot-mix pavements.

Trinidad is the safest asphalt for durability. Trinidasco cold-laid pavements have a high coefficient of friction, and are safe for modern traffic.

Trinidasco cold-laid pavements are used for new construction . . . for resurfacing . . . for maintenance. Trinidasco is convenient . . . can be laid with hand tools or mechanical devices immediately after preparation, or from stock piles.

Specifications and full particulars covering mixtures for asphaltic concrete, asphalt m a c a d a m and sheet asphalt (binder and top) pavements furnished on request.

THE BARBER ASPHALT COMPANY

Philadelphia

NRA MEMBER U.S. WE DO OUR PART

New York Chicago St. Louis

of 37 in. has been established. Long experience and close observation of drafting room practise has determined the new height the proper working height for a four-post table. In establishing this height as a standard, the use of raising blocks is eliminated.

Drawing boards on the tables are made of high quality California sugar pine, selected for close, smooth grain without any hard spots. They are varnished on both sides and the top surface is sanded smooth. Cadmium-plated steel end cleats are attached to accommodate the new Hamilton parallel rule device. The end cleats provide a correct and accurate surface for T-squares. The parallel rule device and dust covers are extra equipment.

The drawing boards are adjustable for slant and equipped with a standard tilting device on each side. Special features incorporated in construction include bolts on the lower front legs for attaching the new Hamilton-Calumet coaster drafting chair and footrests with a brass angle on the front edge to prevent wear.

The drawer arrangement illustrated is probably the most popular and widely used arrangement developed for four-post drawing tables. It consists of one large shallow drawer for tracings and papers, at the left, and a tool drawer at the right, equipped with lock, sliding tool tray and compartment for ink bottles. Other drawer arrangements for added storage of materials and supplies are available.

▼

New Utility Concrete Breaker

The Concrete Cutting Corporation of America, 52 Clark St., Brooklyn, N. Y., announces a trailer type concrete breaking machine to meet the needs of utility companies, municipalities and contractors.

This machine is light in weight, sturdily built, well balanced on its axles and very mobile.

It can be trailed behind any truck-mounted compressor or handled by hand in breaking out floors in buildings. It has a horizontal movement of 6 ft. and will cut a width from 6 in. to 6 ft. wide. The hammer is suspended in two journals allowing the operator to move the hammer ahead or back in order to gauge the cut. It is controlled entirely from the rear seat, requiring only two men to operate it. Any type 160 cu. ft. or larger compressor will handle it.

New Concrete Breaker

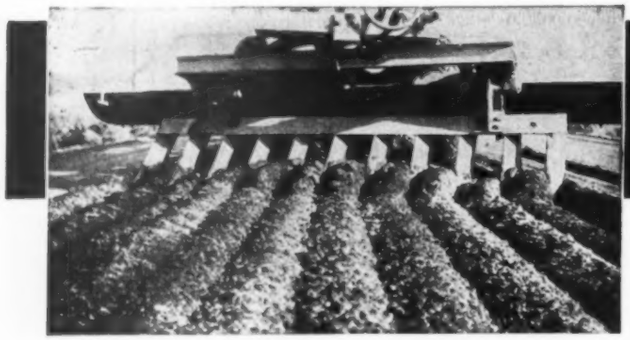
▼

New Heavy Duty Pulsator

The Smith Engineering Works, Milwaukee, Wis., has recently developed a new heavy duty pulsator, designed to screen sand, gravel, crushed rock, ore or coal, wet or dry, all uniformly.

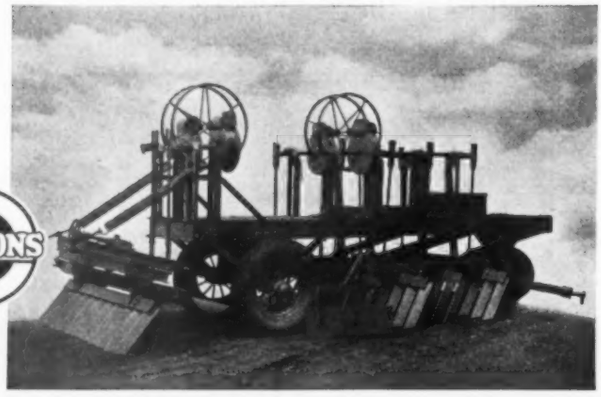
The eccentric action of the pulsator produces a circular movement which makes the aggregate literally dance over the wire. The movement is stated to produce a maximum screening action, uniform on every inch of the wire, on every deck and under any load.

The frame is horizontal, more compact, rigid and easy to



PARSONS
TURBO MIXER

REDUCES COSTS
IMPROVES OUTPUT



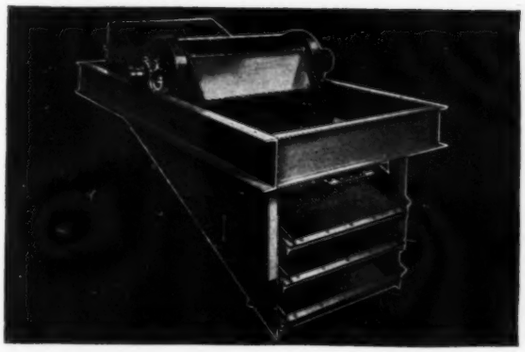
THE Turbo has already been approved in eight states under widely varied specifications and materials.

(a) Better application of the tractor power.
(b) Greater depth of material handled.
(c) Faster mixing action.
(d) More uniform results in texture and finished surface.
(e) Better application of power saves time and fuel.
(f) Doubles the effectiveness of present tractor or blade equipment.
(g) Handy to operate—easily transported.

Write for details. We have a representative near you.

THE PARSONS COMPANY, INC.
NEWTON IOWA

When writing to advertisers please mention ROADS AND STREETS—Thank you.



Telsmith Pulsator.

install. The shaft is journalled in a complete, self-contained independent unit . . . mounted on the frame . . . with the screen decks easily unbolted therefrom. The vibrator unit may be readily removed and taken apart in the field so that repairs, when they finally become necessary, may be made with the utmost convenience.

The nested springs are centrally located, to assure uniform support at all points of the deck. These springs carry practically all the load of both decks and aggregate, thereby greatly lengthening the life of the end bearings.

The New Telsmith Pulsator is made in 8 sizes from 2x6 to 4x12—single, double and triple deck.

▼

New Pioneer 40 x 20 Roll Crusher

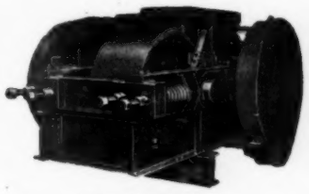
The 1935 model Pioneer 40x20 roll crusher has been announced by the Pioneer Gravel Equipment Mfg. Co., Minneapolis, Minn.

The Pioneer 40x20 roll crusher has manganese shells 40 in. in diameter, 20 in. wide, carried on heavy shafts mounted in Timken bearings, fully enclosed in self-aligning dust-proof housings which permit deflection without impairing the grease seals.

All gears are chrome-molybdenum steel, fully enclosed and running in oil; the drive gears have cut teeth and the star gears are designed for the severe service required for crushers.

The adjustment of the crusher opening is positive and remains fixed regardless of the tension on the springs. The result is less pulverization.

The maximum stage of reduction is 2 in. and the opening



40 x 20 Roll Crusher

can be set to produce from 2½ in. down to No. 10 mesh. It is stated the crusher will average about 90 tons per hour producing 1 in. minus or 35 tons per hour producing ¼ in. minus.

▼

New Joint for Concrete Pavement

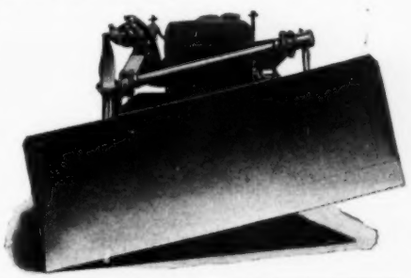
Proper dowel design is claimed to be one of the important features of a new joint placed on the market recently by L. J. Mensch, M. Am. Soc. C. E., 307 North Michigan Ave., Chicago. The dowels used in this joint have an outside diameter of 1 5/16 in., have a strength about 2½ times and a stiffness nearly 5 times of that of a ¾-in. dowel. They are welded to a stiff structural channel which is filled in the shop with rich mortar and are automatically held in a parallel position. The resilient filler is made of asphalted wood fiber or celetex or

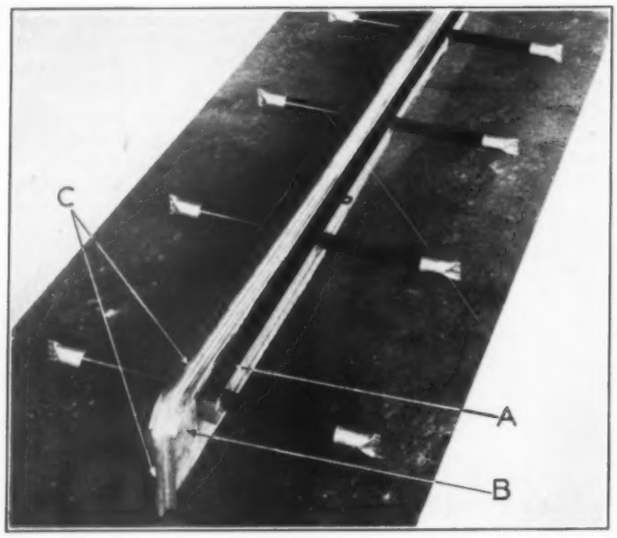
Dirt-Movers are Turning to Continentals—

The popularity of Continental equipment — Bulldozers, Trailbuilders, Wagon Scrapers, Rippers and Snow Plows — is proved by the large number of repeat orders for Government, State and County projects and individual contractors. These units in conjunction with any of the crawler tractors are moving dirt and other material at surprisingly low yardage costs. Dynamic Steel — the steel with unusual fatigue-resisting ability — gives Continental Bulldozers, Trailbuilders and other units the "gaff" to stand up under the most gruelling punishment. The Continental Heavy-Duty Bulldozer can be converted into a Continental Trailbuilder or a Snow Plow at small cost. Write for descriptive material on the new Continental Wagon Scraper and RollClear Ripper.

CONTINENTAL ROLL & STEEL FOUNDRY CO.
INDUSTRIAL EQUIPMENT DIVISION
CHICAGO **332 South Michigan Ave.** **ILLINOIS**
General Offices East Chicago, Ind.

The Heavy-Duty Bulldozer blade can be tilted, as shown at the right, so the Bulldozer can also be used for grading. The tilting of the blade is done hydraulically without the operator leaving the tractor seat.





Unit Dowel Joint with Resilient Filler—Dowels Are Held in Alignment by Structural Steel Member "A." Top, Sides and Occasionally Bottom of Resilient Filler "B" are Sealed by Zinc Cap "C" Against Intrusion of Water and Mineral Matter.

cork, generally ⅞ in. thick for expansion joints and about ½ in. thick for contraction joints.

The water and dirt-proof seal at the top and sides is formed by a zinc cap. For extremely poor soil conditions a seal cap at the bottom may be placed. The picture of the joint shows the general stiffness of the whole device which is standing at the subgrade without any support. The entire joint weighs only 120 lb. for a 20-ft. wide pavement and can easily be picked up by two men and set in place. By driving 6 stakes through the clips provided at the channel after the joint is lined up, all dowels are held in proper position.

The cost of this joint can be further reduced by adopting the French practice of omitting the zinc seal cap and using instead a cement colored rubber cement on top of the filler and at the sides. This cement is stated to stick tenaciously to the concrete and resilient filler, to allow an expansion of several 100 per cent, does not get hard in the lowest temperatures encountered in the Middle West and does not disfigure the pavement. Another great advantage claimed for this joint is that it prevents creeping of the pavements.

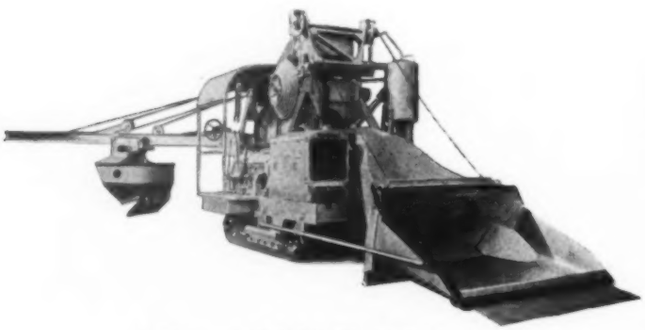
▼

New Paver—"Model S"—27-E

The Ransome Concrete Machinery Co. of Dunellen, N. J., announces a new paver—the "Model S"—27-E.

This model retains those features of former models which experience has shown to have the greatest merit, and in addition the new model is improved and simplified in several ways.

Greater horsepower, a longer boom, auxiliary water tank, and



Ransome "Model S"—27-E Paver

larger pipes from tanks to drum, simplified countershaft construction, larger clutches and troubleproof crawler constuction . . . these are the outstanding improvements in the new "Model S."

It is stated that this paver has maintained an hourly average of approximately 39 batches per hour for 11 hours continuous operation on a 1¼ minute mix.

The year 1935 is the twenty-fourth year for Ransome in making pavers—the eighty-fifth in making the name "Ransome" known wherever concrete is poured.

▼

WITH THE MANUFACTURERS

I. M. Smith Now Assistant General Sales Manager

Announcement has been made by the Central Iron & Steel Co., Harrisburg, Pennsylvania, of the appointment, effective February 1st, of Mr. Irving M. Smith as assistant general sales manager.

Mr. Smith is a graduate of the Peirce School of Business Administration, Philadelphia, Pa., and before associating with the Central Iron & Steel Co. as manager of floor plate sales had been employed for a number of years by the Alan Wood Steel Co., Conshohocken, Pa.

Mr. Smith will remain in charge of advertising, and will retain his headquarters in Harrisburg.

Irving M. Smith

▼

Illinois Company to Make Corrugated Metal Pipe

The Illinois Corrugated Culvert Co., Peoria, Ill., has been organized to fabricate and sell Toncan iron corrugated metal pipe, sectional plate pipe and arches throughout the State of Illinois, according to an announcement by F. A. Kelly, president of the Toncan Culvert Manufacturers' Association.

Construction of a modern culvert fabricating plant is under way at Peoria, but pending its completion, shipments are being made from Danville, where the new company is operating the plant formerly owned by the Canton Culvert Co., Division of Republic Steel Corporation.

Officers of The Illinois Corrugated Culvert Co. are A. E. Hudson, president; K. M. Walters, treasurer and general manager, and Mrs. Minnie Easterly, secretary. Mr. Hudson also operates one of the oldest contractors' equipment companies in Illinois and Mr. Walters has had many years' experience in the sale of corrugated metal pipe in connection with the Capital City Culvert Co. of Wisconsin.

D. R. Sanders of Joliet and H. B. Moore of Springfield, who formerly represented the Canton Culvert Co., have been retained by the Illinois Corrugated Culvert Co. as special representatives, and dealers and direct representatives have been appointed at a number of points throughout the state.

▼

New Loadmaster Distributors

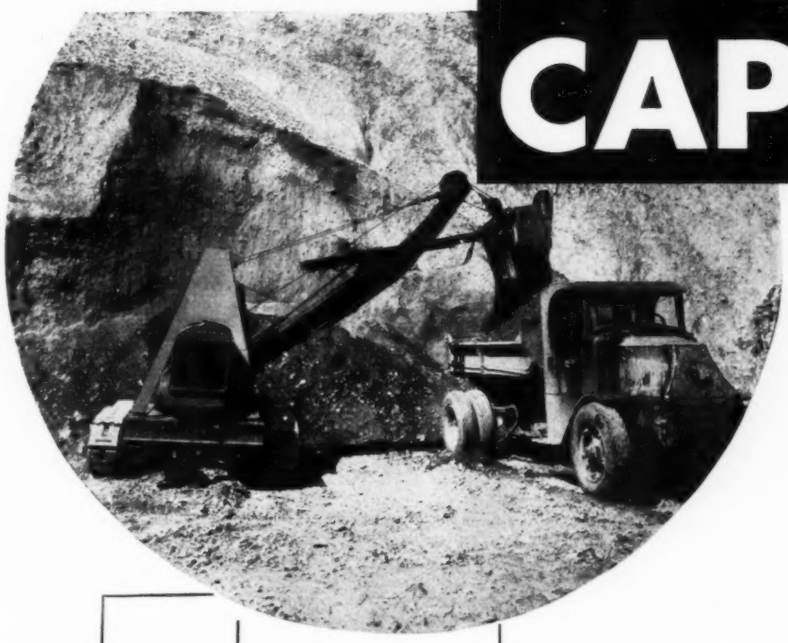
Bucyrus-Erie Co., South Milwaukee, Wis., announces the appointment of the following Loadmaster distributors: Herbert S. Freeman, 49 Darwin St., Rochester, N. Y., for the western portion of New York state; John Bouchard & Sons Co. of Nashville, Tenn., for the central portion of the state of Tennessee. This new distributor can be reached at 11th Ave. N. and Harrison St. in Nashville.

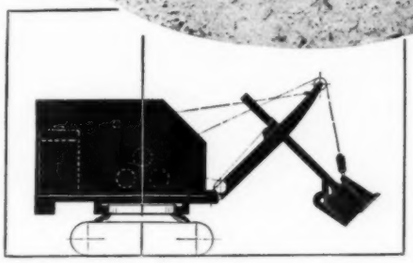
▼

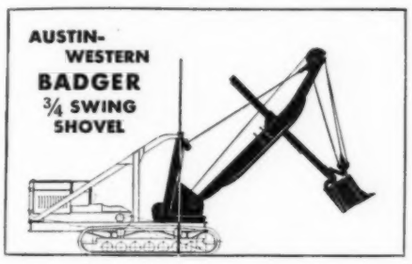
Borchard Now Technical Manager Keystone Portland Cement

Edwin K. Borchard has been appointed technical manager by the Keystone Portland Cement Co. with offices in Philadelphia, New York and Boston. Mr. Borchard has been associated with the Universal Atlas Cement Co. as technical service manager and for many years with the Atlas Portland Cement Co. and the Portland Cement Association in technical and editorial work.

How a SMALL SHOVEL *can be famous for* BIG CAPACITY







PARTS IN BLACK SHOW MASS MOVED ON SWING

● Although not classed among the heaviest of earth moving equipment the Austin-Western Badger Shovel (weighing only 21,250 lbs.) is still definitely a big capacity shovel. Its design is such that the boom is supported by a tripod and counter-balanced by the entire dead weight of the rest of the shovel. In many large shovels the boom is counter-weighted by another weight at the opposite end of the cab—the two pivoting over the chassis which alone remains standing on the ground. Not only the weight of the boom must be *started and stopped* but the opposing mass of the cab and counter-weight as well. Time and energy is wasted starting and stopping with every swing.

In the Badger this dead weight is moved not constantly, but only when the position of the entire equipment is shifted. Since by its more efficient construction the Badger requires less power and less time to start and stop each swing, the result is more savings per hour and equal capacity or greater than equipment twice its size.

The principle of the Austin-Western Badger offers big capacity and speed on many jobs which it has not been customary to figure with lighter shovels. We suggest that you consider the advantages in dollars and cents and hours saved. Send the coupon for details.

The Austin-Western Road Machinery Co.
Home Office: Aurora, Ill. Cable Address: AWCO, Aurora
Branches in Principal Cities

NRA

The Austin-Western Road Machinery Co.
A-2, Aurora, Illinois
Please send us full details on the Austin-Western Badger Shovel.
Name .....
Company 462
Address ..... State .....
City .....

ROAD GRADERS · MOTOR GRADERS · ELEVATING GRADERS · DRAGS
ROAD ROLLERS
Austin-Western
DUMP WAGONS
BITUMINOUS DISTRIBUTORS · ROAD-MIX MACHINES · CULVERTS
SCARIFIERS · BULLDOZERS · TRAILERS · SCRAPERS · PLOWS
DUMP CARS
CRUSHING AND WASHING PLANTS · SWEEPERS AND SPRINKLERS · SHOVELS · CRANES · ETC · SNOW PLOWS

ROADS AND STREETS

with which is merged Good Roads and Engineering and Contracting.
Covering design, construction, maintenance and traffic control

H. P. GILLETTE
Editor

C. T. MURRAY
Managing Editor

A. B. GREENLEAF
Field Editor

J. C. BLACK
Associate Editor

D. G. LEDGERWOOD
Advertising Editor

E. B. HOWE,
Business Manager

Published Monthly by
GILLETTE PUBLISHING COMPANY
DAILY NEWS BLDG.
400 W. Madison St. Chicago, Ill.
Telephone State 5161

New York Office - - - - 420 Lexington Ave.
Telephone Mohawk 4-5040

Cleveland Office - - - - - - - - - - - -
- - 1514 Cohassett Ave., Lakewood, Ohio
Telephone Lakewood 4466

San Francisco Office - - - 155 Montgomery St.

Entered as second-class matter June 25, 1931, at the post office at Chicago, Ill., under the act of March 3, 1879. 25 cents a copy. Annual subscription, $2.00 in the United States; Foreign and Canadian, $3.00 for 1 year, $5.00 for 2 years. Copyright, 1935, by Gillette Publishing Co.

Also Publishers of
POWERS' ROAD & STREET CATALOG
WATER WORKS & SEWERAGE
SPORTING GOODS JOURNAL
MIDA'S CRITERION
MOSAICS & TERRAZZO
OIL & SOAP

Vol. LXXVIII APRIL, 1935 No. 4

CONTENTS

HIGHWAY RECONSTRUCTION THROUGH EARTHQUAKE SHATTERED MOUNTAINS. 119
By T. H. NEVINS

THE LEE BOULEVARD OF GRAVEL AT ITS BEST 125
By J. L. HARRISON

OIL-MIX SURFACES IN LIVINGSTON COUNTY, MICH. 129
By W. J. SLAVIN

SAN FRANCISCO BAY BRIDGE—PRESENT STATUS 132

PROGRESS IN ROAD STABILIZATION BY USE OF CALCIUM CHLORIDE 135
By FRED BURGGRAF

HIGHWAY AND RAIL TRANSPORTATION IN TURKEY 137
By MAHMUT BAGDADI

NEW METHODS AND EQUIPMENT ON ILLINOIS HIGHWAYS . . . 138

ELECTRON-SHELLS, ELECTRON-ATMOSPHERE AND WEATHER . . 140
By H. P. GILLETTE

LONG-SPAN BRIDGES 143
By CHARLES EVAN FOWLER

CAST IRON ROAD SURFACING TEST AT WILMINGTON, DEL. . . 148

LARGE HIGHWAY CONSTRUCTION PROGRAM ASSURED 149

EDITORIALS 150

NEW EQUIPMENT AND MATERIALS 151

WRITE for our new circular showing illustration and description of Olsen Special Bench Type Compression Testing Machine. It is designed especially for testing 2" x 4" cylinders and 2" x 2" cubes. The machine is hydraulic, having two gauges, one to half and the other to full capacity. Capacity ranges of from 20,000 to 80,000 lbs.

TINIUS OLSEN TESTING MACHINE COMPANY
500 North Twelfth St. Philadelphia, Pa.

THE SIMPLICITY SYSTEM COMPANY
ASPHALT PLANTS
RIVERSIDE DRIVE
CHATTANOOGA, TENNESSEE